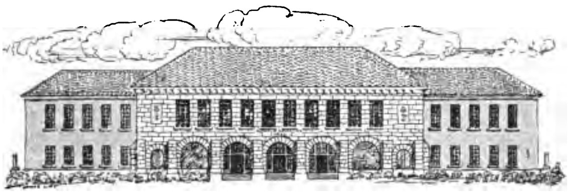
PHYSIOLOGY AND HYGIENE

CALIFORNIA
STATE SERIES



CALIFORNIA STATE SERIES SCHOOL TEXT-BOOKS

PHYSIOLOGY AND HYGIENE

COMPILED BY THE

California STATE TEXT-BOOK COMMITTEE

AND APPROVED BY THE

STATE BOARD OF EDUCATION

SACRAMENTO

W. W. SHANNON, Superintendent State Printing

PREFACE.

In preparing this work for younger students especial pains have been taken to make it clear and simple. Sentences, paragraphs, and chapters have been made short, and a concise summary follows each chapter. So far as possible technical terms have been avoided and English words preferred to Latin, for instance, post-caval vein instead of *vena cava inferior*, spinal bulb instead of *medulla oblongata*, etc. The Latin form of the plural puzzles the student who has not had Latin; hence the English form of the plural is used, as *pleuras*, *ganglions*, *ciliums*, *villuses*, *papillas*, etc.

The illustrations are made clear and distinct, and are labeled directly; that is, the detail labels are on, or very close to, the part labeled, so that time and effort are not needed to associate the thing and the name. A large number of the illustrations are original.

A few simple experiments are given; for although much less can be done than with older students, yet considerable must be done if the subject is to be made clear.

The subject of hygiene has received careful attention; for it must not be forgotten that the main object of this study is that each pupil may learn how to take better care of his own body. It has been the aim not to give mere arbitrary rules of health, to be blindly and implicitly followed, but to base all precepts of hygiene on the general principles of physiology, so that the pupil may understand

the *why* and the *how* so far as possible. His obedience will be more ready and more complete when based on intelligence than when it is simply a submission to a peremptory command. In many cases, too, the general principle will serve as a guide where no rule has been laid down; no treatise can cover all possible contingencies.

At the end of the book is a glossary in which all technical terms are pronounced and explained.

CONTENTS.

TO THE TEACHER.

It is not the fault of the teacher that the human body is very complex in structure and that many of the functions are obscure. Nevertheless the teacher is responsible for making the subject as clear as is possible. To do this it is absolutely essential to perform some experiments and to show some of the internal organs of such an animal as the rabbit, or materials obtained from the butcher. This involves work, and sometimes work that is not altogether pleasant. But no earnest teacher will shrink from work simply because it is not agreeable.

Every school should have a microscope, by means of which to show the corpuscles of the blood, cells from various tissues, the circulation of blood in a frog's web, or in the gills of a tadpole. From various dealers in school supplies there can be purchased mounted slides illustrating most of the kinds of cells and tissues of the body. These can be successfully used by teachers who have not had the advantages of a thorough training in histology.

When studying the bones the teacher can usually borrow some human bones from the nearest physician. Also get a femur of a horse or cow and saw it in two lengthwise. It will show the structure as well as a human femur. It is easy to test the composition of bone by burning and by acid. Corned beef shows well the structure of muscle. A sheep shank from the butcher may be used to show the joints, synovia, cartilage, ligaments, etc. Most pupils will be ready to help dissect a heart and will be delighted to see the action of the valves.

By means of a common bulb syringe and a little glass and rubber tubing the action of the arteries and the nature of the pulse and capillary flow may be illustrated. The circulation of blood in the web of a frog's foot is such an interesting and instructive sight that the teacher should show it to the class *without fail*. Even if the school has no microscope and the teacher without experience, it is often possible to get a near-by physician to show it to the class. The coagulation of the blood is readily shown. The experiments illustrating the action of the

diaphragm are very helpful, and any teacher possessing a modicum of ingenuity and willingness to work can prepare them. In addition to the experiments given in illustration of the chemistry of respiration, it is desirable to show nitrogen and the composition of the air. This can readily be accomplished by following the directions in the larger book or in any chemistry.

To learn the temperature of the body borrow a clinical thermometer from a physician. Have the children make little paper windmills to show the air currents in rooms, over stoves, registers, radiators, etc. The children should test the currents of air at all gratings and registers in the schoolroom by holding a handkerchief up close to them. The teacher should place a board under a window (as directed in this book) to show how to ventilate a room without unpleasant drafts. Each pupil should prepare a section of tooth as directed in this book. When studying the subject of absorption, the teacher should get from the butcher about a foot of the small intestine of a calf. He will wash it clean for a small consideration. Cut this into pieces an inch long. Turn them inside out and place them in shallow dishes of water. The villuses will readily be seen. A piece of the gullet will show the muscular and mucous coats. Have the pupils make a careful study of Fig. 87 and also of Figs. 85 and 86, which are designed to lead up to Fig. 87. If the teacher is willing to practice, he can soon learn to demonstrate muscle action by means of frog's muscle and to show reflex action of the spinal cord with a frog.

Many interesting experiments on the senses can be made with children, such as the test of touch with compass points, keenness of sight, hearing, accuracy of the muscular sense, etc. The internal structure of the eye never fails to awake enthusiasm, and the teacher should show this, and perhaps some of the pupils can also succeed in doing the same. If the teacher can obtain a book on nursing, or, better still, persuade a physician or trained nurse to come before the class, they can learn how to prepare and apply bandages, to dress wounds, to treat for drowning, etc.

ELEMENTARY PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

The Care of a Machine. — In order to take good care of a machine one must know about its different parts, what each part is to do, and the relation of the parts to one another. He must keep the machine clean and well oiled, and must not overwork it. Otherwise it will neither do good work nor last long. This is true not only of machines like typewriters and sewing-machines, but of bicycles, and even of such simple tools as knives and scissors. We would not trust the management of any valuable machine to one who did not know enough to take good care of it.

The Care of the Body. — The care of the body is of vastly greater importance. We can get new parts to replace those worn out in a machine. While we can get artificial limbs, we cannot replace such organs as an eye, the heart, or the lungs. If we do not take good care of our bodies, we cannot keep well, live long, or do good work. So we need to know about the different parts of our bodies, the work that each is to do, and the relation of the parts to each other.

This knowledge is desirable for everybody; but especially necessary for those who live a quiet, indoor life. Indoor people do not get as much exercise or as much fresh

air as those who live outdoors. An indoor life is always more or less artificial, and we need to take especial care that our bodies do not suffer. It is believed that one seventh of the deaths among civilized races are due to lung troubles. Those who live outdoors have little trouble of such kind. We need to learn about the air and breathing, about exercise and bathing, about food and digestion, about blood and its circulation, about the nervous system, etc.

Hygiene. — Hygiene is the art of preserving the health. This is the main object of our study of this subject.

Physiology. — Physiology is the science of the action of the body and its various parts. We must know the natural action of the parts of the body to be able to keep them in good working order.

Organ. — An organ is any part of the body that has a special work to do, as the hand, eye, or heart.

Function. — The work or action of an organ is its function.

Anatomy. — Anatomy is the science of structure. We need to know something of the structure of our bodies. For this purpose we may study the internal structure of the sheep, pig, calf, and rabbit — which is very similar to our own. We can take the hearts, lungs, brains, eyes, and muscles of such animals to learn something of the structure of these organs in our own bodies; if we fail to do this, we can never get a clear understanding of the subject.

Tissues. — Every organ is made up of several different kinds of material. For instance, in a slice across a ham we see skin on the outside, then fat meat, lean meat, and bone. These "primary building materials" of the body

are called *tissues*. A tissue is a collection of similar cells devoted to the same work; or, in other words, a tissue is a set of cells having the same structure and the same function. Thus we have muscular tissue, nervous tissue, bony tissue, etc.

Cells. — The whole body is made up of small parts, called *cells*, which are to be compared to the bricks in a house. These cells are of various shapes in the different tissues. The living material of the body is called *protoplasm*. It is a jelly-like substance resembling the white of an egg, though often presenting a dotted appearance. A cell, in its simplest form, is merely a distinct particle of protoplasm. Each cell usually has, however, a more dense central part, called the *nucleus*. The great majority of cells have a distinct covering or cell-wall. A grape or cherry serves very well to illustrate a cell. The skin represents the cell-wall, the pulp corresponds to the protoplasm, and the seed to the nucleus. (See Fig. 39, Cells of the Epidermis.)

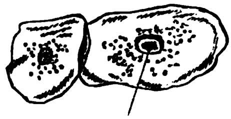


Fig. 1. Epithelial Cells from the Inside of the Cheek.

Division of Labor in a Community. — We are all aware of the advantages of division of labor in a community. If each person learns to do one thing well, all can work together economically for the common good, time is saved, and cheaper and better goods are produced.

Division of Labor in the Body. — In the body there is a division of labor similar to that in a community. In the first place each organ has its special work, and the various organs act helpfully together, each working for all the rest and worked for by them.

The general structure of all the cells is about the same, yet they differ enough for us to tell them apart. They differ more in their work than in their appearance. Each has some one kind of work that it can do well, and to which it devotes itself. The *nerve cells* receive impressions from the outer world, carry nerve currents, and control the various actions of the body. The *muscle cells* have as their work the production of motion.

The Life of Cells. — Each cell must take food for itself and grow. Each has a birth, life, and death, as each individual in a community of men; and as the community continues, while the individual members are constantly changing, so, in the body, while the form remains about the same from year to year (in the adult), the cells are continually changing, some dying, and others taking their places. Thus it is seen that though the cells are packed closely together and though they work in groups, each cell leads, in one sense, an independent life. Like the individual in the community, each lives for itself, yet all work together for the common good.

CHAPTER II.

THE BONES.

The Two Parts of a Skeleton. — The skeleton consists of two portions, (1) the central axis, or spinal column, to which the head belongs; and (2) the limbs and the bones belonging to them.

The Uses of the Bones. — 1. The skeleton gives the form to the body.

2. It supports the softer tissues.

3. It protects softer parts, as the brain in the skull, the spinal cord in the spinal column, the heart and lungs in the chest, etc.

4. The bones serve as levers in producing motion and locomotion.

Study of a Vertebra. — Take a vertebra from the middle of the spinal column: —

1. Its most solid part is its body.

2. On the dorsal side of this is the neural arch, forming with the body the neural ring, through which the spinal cord passes.

3. From this arch there extend projections, or processes. Hold the vertebra by the tip of its longest process, and place it beside the corresponding vertebra in the complete skeleton. Note that: —

(*a*) The body is flattened where it fits against the vertebras above and below it;

(*b*) The holes in the vertebras form a passage for the spinal cord;

(*c*) The middle projection is the spinous process, and the series of spinous processes form the ridge of the backbone;

(*d*) The two side projections are the transverse processes.

Fit together two vertebras in their proper order and observe that:—

(*e*) The openings at the sides, through which the spinal nerves pass, are formed by notches, or grooves, in the two vertebras.

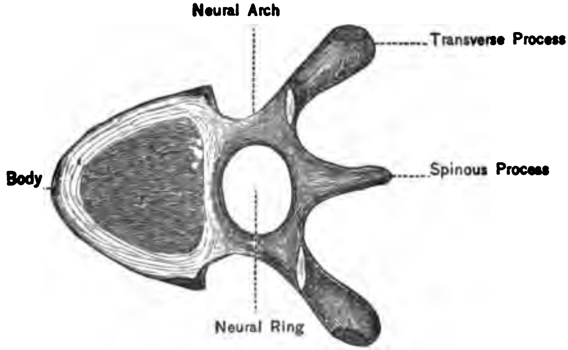


Fig. 2. Upper View of Thoracic Vertebra.

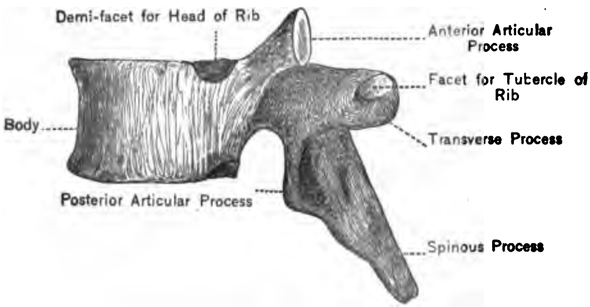


Fig. 3. Left Side View of Thoracic Vertebra.

(*f*) The two projections extending upward from the ring of one vertebra fit against two projections extending downward from the other vertebra. These are the anterior and posterior articular processes.

The Spinal Column. — The central part of the skeleton is the backbone, or spinal column. As a whole it is a

column, widening toward the base, composed of a series of separate bones called *vertebras.*

Each vertebra has seven projections, four for joining other vertebras (two upper and two lower), two side, and one spinous.

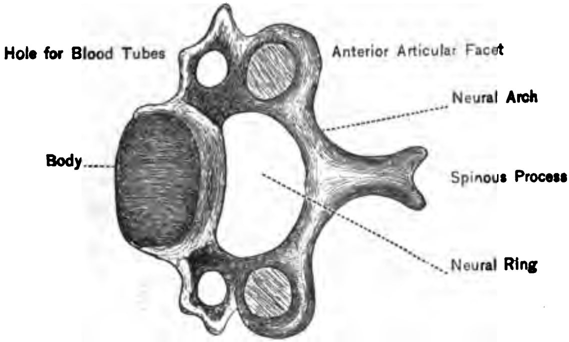


Fig. 4. Upper View of Cervical Vertebra.

Fig. 5. Left Side View of Cervical Vertebra.

How the Vertebras Fit Together. — The smooth places where the projections join are called *facets.* Observe on each side of the body of the vertebra a facet where the head of the rib joined it. There is also a facet on the side process where the side of the rib joined it.

The Cervical Vertebras. — The seven cervical (neck) vertebras have holes through their side projections for the passage of blood tubes.

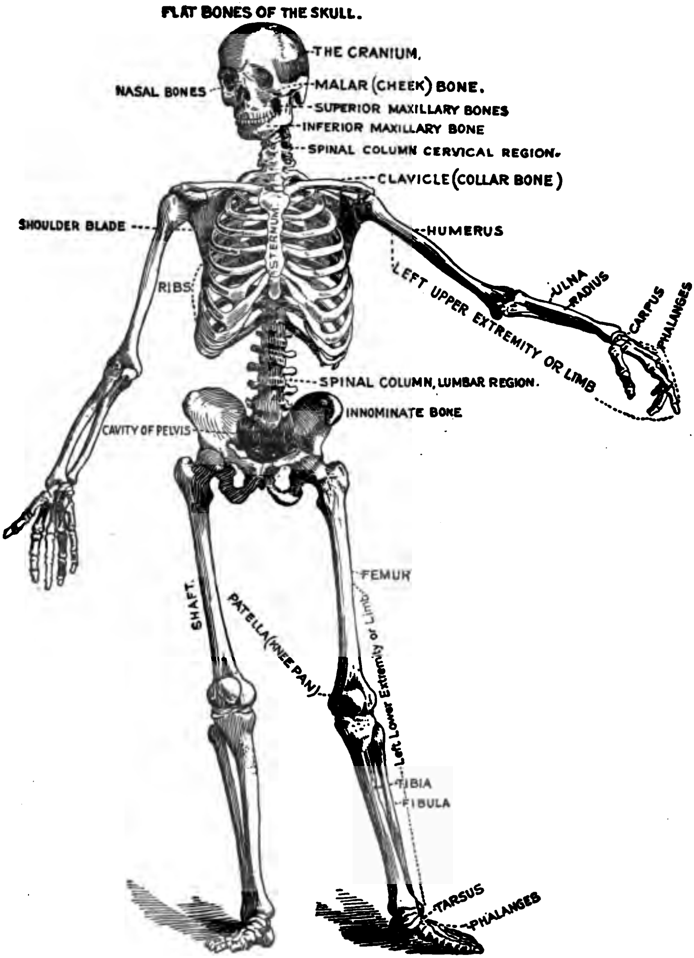


Fig. 6. Side View of the Human Skeleton

TABLE OF THE BONES.

HEAD (28)	*Skull* (8)		Frontal (forehead).
			2 Temporal (temples).
			2 Parietal (side).
			Occipital (posterior base).
			Sphenoid (base).
			Ethmoid (base of nose and between eyes).
	Face (14)		2 Superior Maxillas (upper jaw).
			2 Nasal (bridge of nose).
			2 Malar (cheek).
			2 Lachrymal (inner front corner of orbit).
			2 Turbinated (within nostrils).
			2 Palate (posterior hard palate).
			Vomer (nasal partition).
			Inferior Maxilla (lower jaw).
	Ears (6)		Malleus (hammer).
			Stapes (stirrup).
			Incus (anvil).
CERVICAL REGION (8)			7 Cervical Vertebras (neck).
			Hyoid Bone (base of tongue).
THORAX (37,			14 True, 6 False, 4 Floating Ribs.
			12 Thoracic Vertebras (back).
			Sternum.
UPPER EXTREMITIES (64)	*Shoulder.*		Clavicle (collar-bone).
			Scapula (shoulder-blade).
	Arm.		Humerus (arm).
			Radius } (fore-arm).
			Ulna } (fore-arm).
	Hand.		8 Carpal (wrist).
			5 Metacarpal (palm).
			14 Phalanges (fingers).
LUMBAR REGION (5)			5 Lumbar Vertebras (loins).
PELVIS (4)			2 Innominates.
			Sacrum.
			Coccyx.
LOWER EXTREMITIES (60)	*Thigh.*		Femur.
	Leg.		Patella (knee-pan).
			Tibia (large bone).
			Fibula (outer bone).
	Foot.		7 Tarsal (instep, heel).
			5 Metatarsal (arch).
			14 Phalanges (toes).

Atlas and Axis. — The first vertebra, the atlas, has no body. The second vertebra is the axis. It has a peg which runs up into the atlas. In shaking the head, the atlas, with the head, turns on this peg of the axis. In nodding the head, the head simply rocks back and forth on the atlas.

The Thoracic Vertebras. — The twelve rib-supporting vertebras are the thoracic vertebras.

The Lumbar Vertebras. — The next five are the lumbar.

The Sacrum and Coccyx. — The sacrum is composed of five vertebras grown together, and the remaining four are combined in the coccyx.

Review of the Spinal Column. — Let the eye slowly review the whole spinal column, noting in what points the vertebras are all alike. Note also their differences.

Flexibility of the Spinal Column. — In well-prepared skeletons there are pads of felt which take the place of the layers of cartilage that were between the vertebras. These cartilages are tough and elastic, and firmly attached to the vertebras above and below. They serve both to keep the vertebras apart and to hold them together. When we bend the shoulders to the right, the right edges of these cartilages are compressed, and the left edges are stretched, as a piece of india rubber would be if it were glued between the ends of two spools, and the whole were slightly bent. The cartilages also, by their elasticity, protect the brain from the shock it would receive in jumping, walking, etc.

Curves of the Spinal Column. — View the spinal column from the side. Draw a line representing all its curves.

The Cavities of the Skeleton. — Examine the cavity of the skull. If the class has not a skull which has been sawed across, look into the skull cavity through the hole where the spinal cord joined the brain.

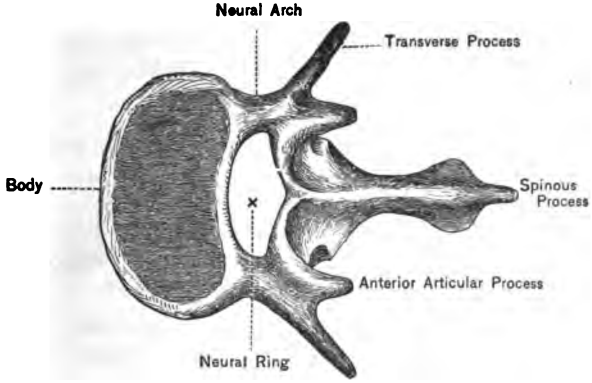


Fig. 7. Upper View of Lumbar Vertebra.

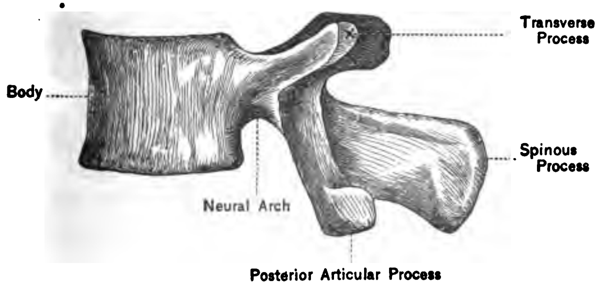


Fig. 8. Side View of Lumbar Vertebra.

Observe the conical shape of the chest. In the entire body the bones and muscles about the shoulders usually make a reversed cone of the upper part of the trunk.

Observe that most of the ribs are connected with the breastbone by cartilages.

The upper limbs are jointed with the body only where the inner ends of the collar bones join the breastbone.

The Skeleton of a Cat or Rabbit. — Examine the skeleton of a cat or rabbit for the sake of comparison. Note especially the skull and spinal column. This knowledge will aid in understanding the brain and spinal cord.

The Weight of Bones. — The bones make about one sixth of the weight of the living body. When dried they may lose half of their weight.

Microscopic Structure of Bone. 1. Examine with a Hand Lens. — Hold a mounted cross-section of bone up to the light and examine with a hand lens. The solid part of the bone will be seen to be pierced by many small holes (or if the holes are filled, they will appear as black spots). These are the cross-sections of the canals, through which run the blood tubes, mainly lengthwise, through the bone.

2. **Examine with the Low Power of a Compound Microscope.** — Examine the section under the microscope, using a half-inch objective. The bony matter will now be seen to be arranged in rings around the canals, somewhat like the rings seen on the end of a log.

Between the rings are circles of elongated dark dots. These are cavities in which were the live bone-corpuscles which built up the bone. The bone was at first cartilage. Later, mineral matter was deposited, forming true bone.

3. **Examine with a High Power.** — Now examine the section under a one-fifth-inch objective. From the dark cavities there run out, in every direction, little crevices, appearing as fine black lines. Through the haversian canals, lacunas, and crevices, the nourishing materials of the blood reach all parts of the bone.

The Chemical Composition of Bone. — 1. Take a tall, narrow jar, or a lamp chimney corked at one end, and nearly fill with water. Add one sixth as much hydrochloric acid. Put into this a slender, dry bone, such as a fibula or rib. In twenty-four hours take it out, rinse it thoroughly, and examine it. The acid will probably have dissolved out the mineral matter and left the animal matter so soft that it may be tied into a knot.

2. Lay a piece of bone on a shovel, or piece of sheet iron, and place in the fire. The animal matter is burned out, leaving the brittle mineral matter.

Composition of Bone. — Bone is composed of two thirds mineral matter and one third animal matter; in childhood the animal matter is in larger proportion, while in old age the mineral matter is in excess. The mineral matter is chiefly phosphate of lime, while the animal matter is largely gelatin.

Fig. 9. Cross-section of Bone. (Highly Magnified.)

Classification of Joints. — 1. Immovable, such as the joints between the bones of the skull;

2. Mixed, such as the joints between the vertebras;
3. Movable, which allow free motion between the parts;

(*a*) Ball and socket, as in the hip and shoulder;

(*b*) Hinge, as in the knee and elbow;

(*c*) Pivot, as in the forearm, and between the atlas and axis;

(*d*) Gliding, as between the short bones of the wrist and of the ankle.

Study of Joints. — Examine these joints in the prepared skeleton, and so far as possible, in sheep shanks, or in fresh specimens of rabbits. Compare the ball and socket joints of the hip and shoulder. Also compare the hinge joints of the knee and elbow.

Hygiene of the Bones. — Sometimes the bones of children are lacking in mineral matter, and are too soft and flexible. This is true in a disease called *rickets*. Even if the bones are natural, children should not be encouraged to walk early, as bow-legs may result. Most bow-legged persons seem to be active, and probably their muscles developed faster than the bones. Unnatural positions or over-use of special groups of muscles may result in lateral curvature of the spine. The height of seats and desks should be carefully looked after.

Sprains and Dislocations. — Sprains and dislocations are injuries to the joints, and often bring more serious results than a broken bone. There should, usually, be complete rest until the part can be used without pain. Otherwise a stiffened joint may result. Hot water applied to a sprain or bruise with rubbing will reduce soreness and may prevent discoloration. But if there is inflammation, cold water should be applied. Bandages may be needed for support.

Broken Bones. — When a bone is broken, of course a physician should be sent for. Care must be taken that the limb be kept straight. If this is not done, the sharp ends of the bone (see Fig. 22) may cut or tear the surrounding tissues, or even cut blood tubes. So, if the person must be carried, it is well to tie a piece of board under the limb to keep from bending it. A cane, umbrella, or any light rigid bar will serve for this purpose.

Summary. — 1. The skeleton consists of the central axis and the limbs.

2. Each vertebra consists of a body, ring (around spinal cord), and processes.

3. Pads of cartilage connect the vertebras.

4. Throughout the bone there are tubes and crevices through which it receives its nourishment from the blood.

5. Bone consists of animal matter with limy matter embedded in it.

6. Sprains should be treated carefully to avoid stiffened joints.

Questions. — 1. Why do the bones of old people break so much more easily than those of children?

2. What is the use of the central marrow?

3. What is the work of the red marrow in the spongy ends of the bones?

4. What are "sesamoid" bones?

CHAPTER III.

MUSCLES AND MOTION.

✓ **Motion and Life.** — Motion is one of the surest signs of life. While we are sitting still, as we say, there are frequent slight motions of the head, body, and limbs. Even during sleep the movements of breathing may be seen; the hand laid upon the chest may feel the beating of the heart, and the finger detect the pulse in a number of places. We must move to get our food, or at least to eat and digest it. We often move to avoid injury. Motion is necessary for speech and in the use of the sense organs. How are all these motions produced?

✓ **Experiments with the Muscles in our own Bodies.** — 1. Clasp the front of the right upper arm; draw up the forearm strongly and as far as possible. Note the changes that are felt in the biceps muscle.

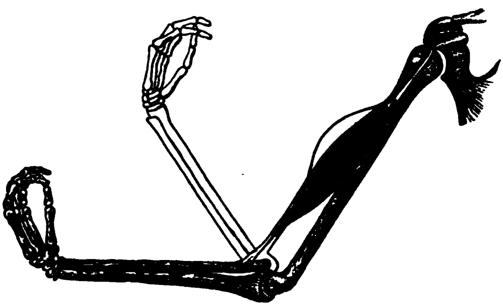


Fig. 10. The Shortening and Thickening of the Biceps Muscle in raising the Forearm

2. Repeat the experiment, and with the thumb and finger feel the cord, or tendon, at the lower end of the muscle, just within the angle of the elbow.

3. Span the muscle, placing the tips of the fingers in the angle of the elbow, and the tip of the thumb as far as you can up the arm; again bend the arm. What change in the muscle does this show? Any muscle that bends a limb, as does the biceps, is called a *flexor* muscle.

4. Clasp the back of the upper right arm; forcibly straighten the arm. The muscle lying along the back of the arm is the triceps muscle. It is called an *extensor* muscle because it extends, or straightens, the arm.

5. Clasp the upper side of the right forearm near the elbow; clench the right hand quickly and forcibly; repeat rapidly.

6. Notice the mass of muscle at the base of the thumb; pinch the forefinger and thumb strongly together. What changes can be seen and felt?

7. Place the hand on the outside of the shoulder; raise the arm to the horizontal position; repeat with a weight in the hand.

8. Stand erect with the heels close to each other, but not quite touching; let the arms hang freely by the sides; rise on tiptoes, without moving otherwise; repeat ten times.

9. Place the tips of the fingers on the angles of the lower jaw; shut the teeth firmly, and note the bulging of the masseter muscle.

10. Press the fingers on the temples; again shut the jaws firmly, and feel the action of the temporal muscles.

By these experiments we learn that when a muscle works it becomes shorter, thicker, and harder.

The Action of Muscle. — The action of muscle is always a "pull." The muscle shortens, at the same time thickening and hardening. It must be kept clearly in mind that the work of the muscle is done by its *shortening* and not by either the hardening or thickening. But the hardening and thickening are often more noticeable than the shortening, and by means of them we may locate the muscle that is producing any motion.

Action of Frog's Muscle. — The action of muscle may be seen much more clearly in a frog's calf muscle, as shown in Fig. 11. When the nerve is stimulated at "A" a nerve impulse runs along the nerve to the muscle and makes it shorten and widen, raising the weight as shown in the right half of the figure.

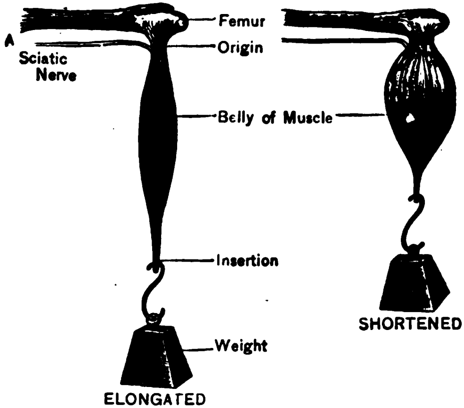


Fig. 11. Action of the Calf Muscle of the Frog, showing the Relations of the Sciatic Nerve.

Structure of Muscle. — Chipped beef shows well the structure of muscle. The white network is connective tissue. Its work is to hold the parts of the muscle together and to support the muscle as a whole. In the meshes of the white network is the red muscle tissue. The partitions which run all through the muscle are continuous with the muscle sheath, and both are continuous with the tendons at the ends of the muscle. In fresh muscle the sheath and the partitions are transparent, and are not very easily noticed. When meat is cooked or salted the connective tissue becomes white and opaque.

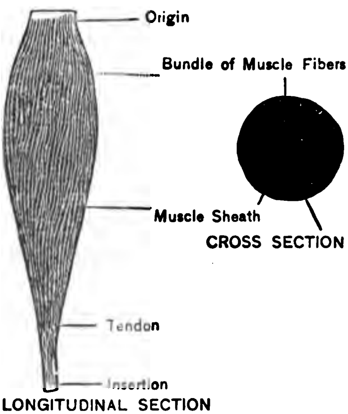


Fig. 12. The Structure of Muscle.

Microscopic Structure of Muscle.—If a tiny shred of muscle, such as you may remove from the teeth with a toothpick, be put in a drop of slightly salted water and examined under a good microscope, the fibers may be seen. These are small thread-like bodies, with cross markings, from which they are called *striated* or *striped muscle fibers*. From the fact that they are under the control of the will they are called *voluntary* muscle fibers. Not all striated muscle fibers are voluntary. The heart muscle fibers are in a special class, being striated but involuntary. The muscles connected with the bones are called *skeletal muscles*. They are all striated and all voluntary.

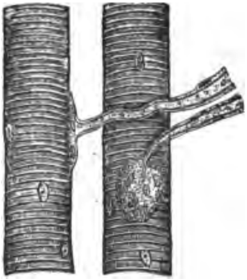


Fig. 13. Two Striated Muscle Fibers showing the terminations of the Nerves.

Plain Muscle Fibers.—In the walls of the arteries, of the gullet, the stomach, the intestines, the bladder, and elsewhere, there are muscle fibers of a different kind from those of the skeleton. These fibers are spindle-shaped cells, as shown in Fig. 14, with a nucleus near the center, and do not have the cross-markings. Hence they are called *plain*, smooth, or un-striated muscle fibers. Owing to the fact that they are not under the control of the will they are called *involuntary* muscle fibers.

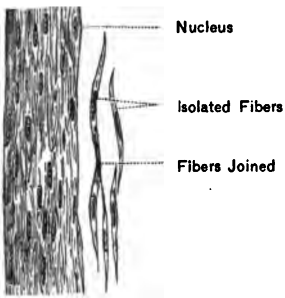


Fig. 14. Plain (unstriated) Muscle Fibers.

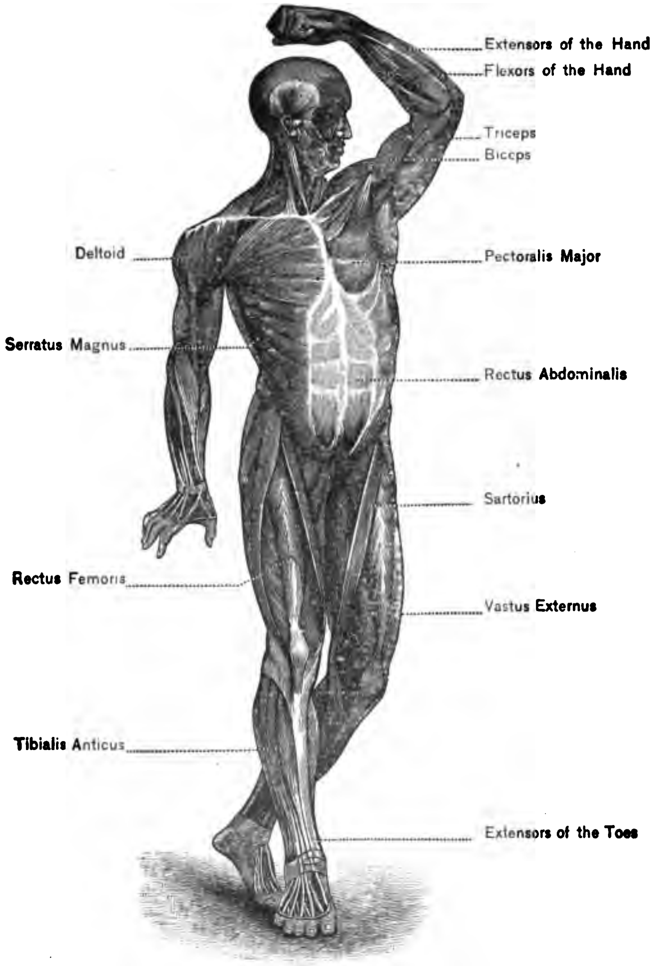


Fig. 16. Front View of the Superficial Muscles.

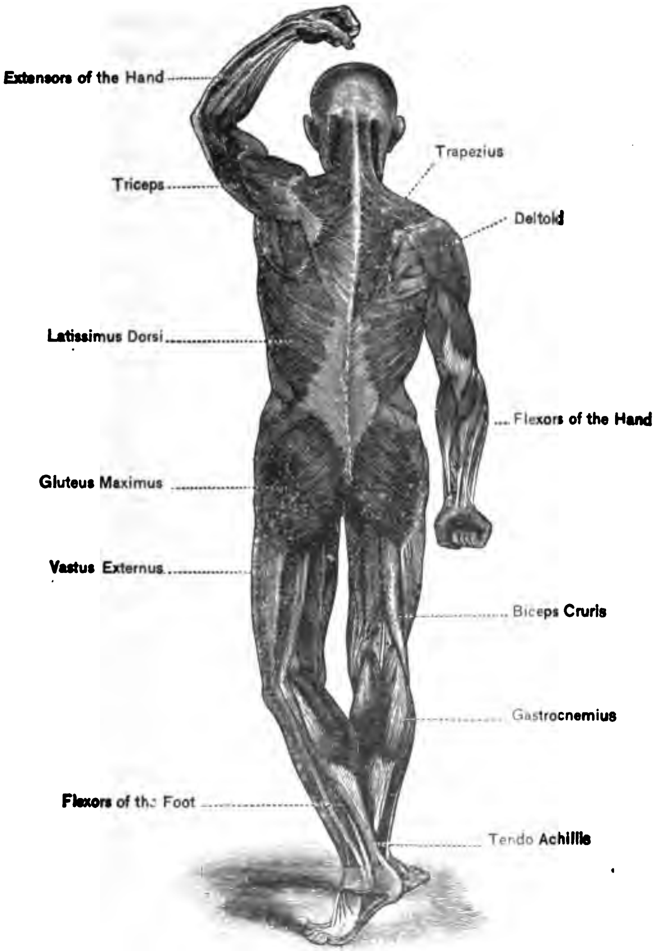


Fig. 17. Back View of the Superficial Muscles.

force, no motion will be produced. Sometimes this is done on purpose, as when, in wrestling "square-hold," one holds the arm rigidly bent at a right angle, to keep his opponent from either pushing or pulling him. In the body are many flexors and extensors "paired off"; they act alternately, like the biceps and triceps in the arm.

Symmetrical Development of the Muscles. — The muscles of the two sides of the body are the same in number and arrangement. At birth they are probably about equal in size, weight, and strength. Most persons early become right-handed, and the greater use of the right hand and shoulder makes the muscles of this side larger and heavier. The muscles pulling on the bones slightly modify them in shape. The whole body may become noticeably one-sided. Most persons step harder on one foot than on the other, as shown by the sound of the footstep, or by the constant wearing of one shoe sole or heel faster than the other. In many persons one shoulder is carried higher than the other.

To Overcome One-sidedness. — Symmetrical development should be carefully sought, and any tendency to a one-sided development should, so far as possible, be avoided. We should use the left hand more. There are many advantages in being able to use either hand. In carving, in shaving, in bandaging, in giving medicine, it may be necessary to use the left hand skillfully. The pianist and the harpist use the two hands about equally, while the violinist puts much more skill into his left hand. Trainers of athletes often begin by developing the left side of the body till it equals the right in size and strength.

Muscles the Source of Strength. — Our strength depends on our muscles. It is a fine thing to have strong, well-

developed muscles, not only because they give beauty of form, but because extra strength and endurance may be needed in case of accident, to save one's own life or that of others. In a case of fire the ability to climb, to go up or down a rope "hand over hand," may be all-important. Any one's life may depend on his ability to run far and swiftly, to swim, to jump, or to lift a heavy weight.

The Number of Muscles. — There are over five hundred muscles in the human body. These vary in size from less than an inch in length, in the ear and in the larynx, to a foot and a half long in the thigh.

The Arrangement of Muscles. — The muscles of the two sides of the body are paired, and naturally are about equal in size and strength. The muscles of the limbs are further paired into flexors, which bend, and the extensors, which straighten the limbs. The muscles are also arranged more or less in layers. There is generally an outer layer and a more deep-seated layer.

Forms of Muscles. — Muscles are of various shapes. The prevailing form in the limbs is spindle-shaped, or fusiform. Some muscles are flat, some have their fibers arranged like the barbs of a feather, and are hence called penniform. Some muscles have a tendon in the middle which runs through a loop, as in the case of the muscle which depresses the lower jaw. Muscles which close openings are circular, and are called sphincter muscles.

Peculiar Muscles. — The diaphragm is a sheet of muscle that forms a partition between the chest and the abdomen. It is arched, and has a clear tendinous center. The abdominal muscles form a wall to hold the organs of the abdominal cavity. These muscles also aid in breathing,

especially in forced expiration, as after violent exercise and in coughing. The abdominal wall consists of several layers of muscle.

Muscles of Expression. — The facial expression is due to the action of the muscles of the face, which in turn are under control of the cranial nerves. The habitual position becomes somewhat "fixed," so it is true that character is often shown by "the looks." Cultivation of happy thoughts therefore tends to make one better looking.

Muscles and Fat. — Fat fills in space between muscles, and, if abundant, forms a layer over the muscles. One notable instance is the hollow triangular space between the muscles of the cheek. If there is very little fat, a depression is seen, forming the "hollow cheeks." But an abundance of fat makes a corresponding elevation.

Convulsions. — These spasmodic actions are due to disordered action of the muscles, and to a disturbed action of the nervous system that controls the muscles. Various disturbances, such as indigestion, may by reflex action bring on convulsions.

Summary. — 1. Motion is involved in nearly every action of the body.

2. The action of muscle is a shortening, accompanied by a thickening and hardening.

3. Muscle consists of fibers with a connective tissue sheath for each fiber, bundle of fibers, and for the muscle as a whole.

4. The skeletal muscle fibers are striated.

5. The muscles make about half the body's weight.

6. Muscles can remain shortened only a little while.

7. The muscles should be developed symmetrically.

8. There are about five hundred muscles in the body.

9. The muscles of the two sides are alike.

10. The muscles of the limbs are spindle-shaped.

Questions. — 1. What effect is produced by carrying a heavy satchel for a long distance without resting?

2. Which is more tiresome, standing still or walking? Why?

3. When the boy, who thinks he can strike a hard blow, says, "Feel my muscle," does he usually call attention to the muscle used in striking?

4. Why are the sides of the body often sore after walking on icy pavements?

CHAPTER IV.

THE MUSCLES AND THE BONES.

Skeletal Muscles. — When we look at the skinned carcass of an animal in the market, we observe that the muscles almost completely cover the bones. Those which are attached to the bones are called *skeletal muscles*. They act upon them as levers, making the motion strong, quick, and accurate. Without bones our motions would be like those of an earthworm or slug, slow and uncertain. The muscles, acting through the bones, can lift a weight that would crush the muscles if laid directly upon them, while a bone, able to support a heavy weight without being crushed, has no power in itself. The muscles have *active* strength, the bones have *passive* strength.

Relation of the Muscles and the Bones. — Examine Figs. 10, 16, and 17. For this work you should have the bones of an arm. Locate the biceps muscle in its relations to these bones as shown in the figures. Feel the biceps of your arm. Note that its thickest part is opposite the most slender part of the bone. But at the enlarged end of the bone the muscle has narrowed to a slender tendon which passes over the joint to be attached to the next bone, thus giving more slenderness, flexibility, and freedom of motion to the joint. Most of the skeletal muscles are attached to bones. There are some exceptions, such as the circular muscle which closes the mouth when the lips are pursed up.

X-Rays and their Use. — By means of X-ray apparatus

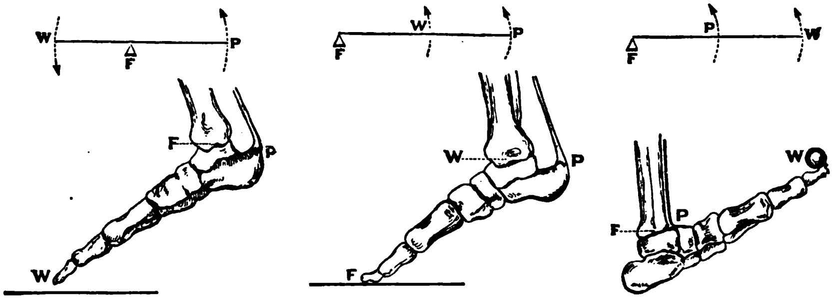
Fig. 18. X-Ray Photograph of Hand showing Shot carried for Twenty Years.
(From *Recreation*, by permission of G. O. Shields.)

the physician can photograph through the body and show the location of the bones. This process is useful in showing injuries to the bones. It is also especially useful in

locating a bullet or other solid body in the flesh, which probing often fails to discover.

Levers. — The main facts to be learned about a lever are that it is a rigid bar; the point about which the lever turns is called the *fulcrum;* the place where the power is applied is called the *power;* and the part to be moved is called the *weight.* In the body, the fulcrum is some joint, the power is the place where the muscle is attached, and the weight is the part to be moved.

Kinds of Levers. — There are three kinds of levers. In the first class the fulcrum is between the power and the weight, as in prying over a block with a crowbar. In the second class the weight is between the power and the fulcrum, as in a wheelbarrow. In the third class the



(1) Tapping on Floor. (2) Rising on Toe. (3) Lifting Weight.

Fig. 19. Three Kinds of Levers as shown by the Foot.

P — *Power.* W — *Weight.* F — *Fulcrum.*

power is between the fulcrum and the weight, as in raising the forearm (see upper part of Fig. 19). We may find many examples of levers in the body if we look for them.

Kinds of Levers shown by the Foot. — The different

classes of levers may be illustrated by different motions of the foot. In tapping the toes on the floor while the heel is lifted, or in pressing down the ball of the foot while running the treadle of a sewing machine, we have an example of a first-class lever. In raising the weight of the body on tiptoes, or as the foot is used in taking each step, the foot is used as a lever of the second class. When one lifts a weight with the toes, the foot is used as a lever of the third class. (See Fig. 19.)

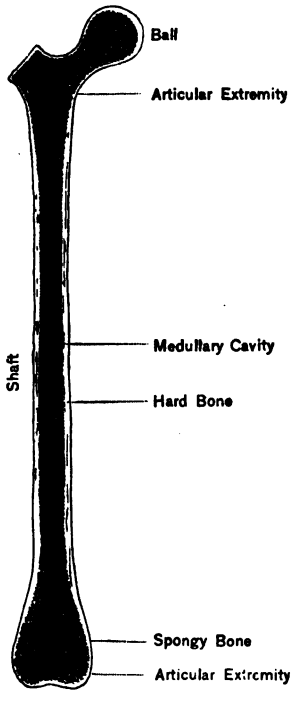


Fig. 20. Longitudinal Section of Femur.

Advantages of Levers in the Body. — If the arm consisted merely of the biceps muscle, suspended from the shoulder, it is evident that its only action would be a straight pull. Suppose the biceps, thus hanging alone from the shoulder, had a hook at its lower end, it could, when it shortened, lift a weight just as far as it shortened, and no farther. It could not swing the weight outward, or push it upward. But from the way in which the biceps is attached to the forearm (see Fig. 10), when the muscle shortens an inch it may move the hand a foot. Of course the hand moves much faster, and we have a great gain in speed by reason of this lever arrangement. But we cannot lift so heavy a weight at this faster rate, as we could at the elbow.

Study of One of the Long Bones. — For this, take, preferably, a femur or a humerus. Let us suppose we have a femur.

1. Observe its shape, — cylindrical, somewhat curved, enlarged at the ends.

2. The ends have smooth places, where they fitted other bones.

3. Along the sides, especially near the ends, are ridges and projections, where the muscles were attached.

4. There are small holes in the bone, where blood tubes passed in and out.

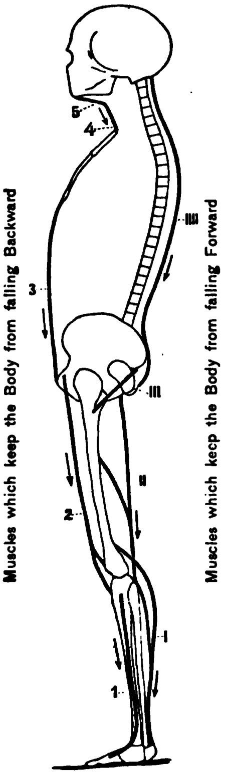


Fig. 21. Action of the Muscles in Standing.

5. Saw a femur in two, lengthwise, and make a drawing showing: —

(*a*) The central marrow cavity.

(*b*) The spongy extremities, noting especially the directions of the bony plates and fibers.

6. Observe the width of the lower end of the femur, where it rests on the tibia. Suppose these two bones were as narrow at their ends, where they meet to form the knee joint, as they are at their centers, what kind of a joint would they make? Illustrate by piling up a number of spools on end; the column is more lightened than it is weakened by the hollowing out of the sides of each spool. And the central hollow of the spool does not greatly weaken it.

Joints. — The ends of the bones, where they fit together in the joints, are covered with a layer of smooth, elastic, whitish or transparent cartilage. The motion in the joints is made still more easy by the synovia, resembling white of egg. The ends of the bones are held together by tough bands and cords of *ligament*, a form of connective tissue very much like tendon. Bones are closely covered by a tough coat of connective tissue called the periosteum.

All these structures can easily be found by dissecting a sheep shank gotten from the butcher, or in the hind leg of a rabbit.

Standing. — Although we are not ordinarily conscious of the fact, when we are standing still we are using many muscles. The accompanying figure illustrates how some of the muscles act in keeping the body upright. Our

weight, or, we would better say, the force of gravity, is continually trying to pull us down to the ground. The joints are all freely movable, and hence as soon as the muscles cease to act properly, in balancing against each other, we lose our balance, and fall if we do not quickly regain it.

Walking. — In walking, we lean forward, and if we take no further action we fall. But we keep one foot on the ground, pushing the body forward, while the other leg is bent and carried forward to save us from the fall. We catch the body on this foot, and repeat the action. To show how we are really repeatedly falling and catching ourselves, recall how likely one is to fall if some obstacle is placed in the way of the foot as it moves forward to catch the weight of the body.

Running. — In running, the action is more vigorous. The force exerted by the rear leg is now greater. It gives such a push as to make the body clear the ground, whereas in walking, the rear foot is not lifted till the front foot touches the ground. But in running there is a time when both feet are off the ground.

Locomotion by Reaction. — Take two broomsticks and place them crosswise under the ends of a board. Run along the board. This shows that the direct effort in running is to push one's support from under him. Our effort in moving forward is to push the earth out from under us, and it is by reaction that we go forward. It is the same problem with the fish swimming forward by striking backward and sideways against the water, and with the bird beating downward and backward upon the air.

Bones combine Lightness and Strength. — The muscles, then, make use of the bones as levers. We carry these levers with us all the time. Hence the desirability of having them light as well as strong. A hollow pillar or hol-

low tube has greater strength than the same amount of material in the form of a solid cylinder. The long bones of the limbs are hollow, and near their ends, where we have found that they need to be enlarged, we find a spongy structure, where lightness and strength are secured by the interlacing fibers and plates of bony material.

Muscles always Stretched. — The muscles are always slightly stretched, as shown by the fact that when a cut is made into a muscle the wound gapes open; the tension of the muscle is further shown by the fact that when a bone is broken, as in the upper arm or thigh, the ends of the bones may slip by each other, and the limb has to be strongly stretched to bring the ends back together. Muscles act better when slightly stretched, and probably need a slight resistant action of the opposing muscle.

Fig. 22. Fracture of the Humerus.

What makes the Muscles act in Harmony? — Have you ever seen two persons, one using the right hand and the other the left, try to sew, one holding the cloth, the other using the needle? Would they get along well? Suppose one were to hold the needle, and the other were to try to thread it, each using one hand. Why is it that the right and left hands of two persons cannot work so well together as the right and left hands of one person? What connection is there between the two, that one knows just what the other

is doing and when it does it? Why can two individuals never, with any amount of practice, work so in unity as the parts of the individual?

Let us seek the answer to these questions in the following lessons.

Reading. — "How to Get Strong and How to Stay So," *Blaikie*, "Sound Bodies for Our Boys and Girls," *Blaikie*.

Summary. — 1. In the limbs the muscles are spindle-shaped and have their greatest diameter opposite the central, or narrower, portions of the bones, concealing the fact that the bones are largest at the ends, as is so evident in the skeleton.

2. The bones serve as levers by which the muscles exert their force.

3. The bones of the limbs are hollow cylinders combining lightness and strength.

4. The joints have a smooth motion due to the cartilage and synovia.

5. Locomotion is brought about by reaction.

Questions. — 1. Find other examples of levers in the body.

2. Find examples of the three kinds of levers, not in the body, which we use often.

3. Why is it easier to sit with one leg crossed over the other?

4. How may the arms be used to illustrate the three kinds of levers?

5. Analyze and explain jumping, hopping, etc.

CHAPTER V.

THE GENERAL FUNCTIONS OF THE NERVOUS SYSTEM. — SENSATION AND MOTION.

What makes Muscles Shorten? — We have seen that the muscles have the power of shortening; that in shortening they act on the bones as levers to produce our varied motions. What makes the muscles shorten?

Voluntary and Involuntary Motions. — Some motions we will to make. We will to sit, to stand, to walk, to run, or to stretch out the hand. Such motions, originating in a brain activity, are called *voluntary*. Other motions are *involuntary*. The will does not control the heart-beat. Most persons cannot keep from winking when a quick motion is made toward the face, even if they know they will not be hit. But all of these motions, both voluntary and involuntary, depend upon the nervous system.

The Cerebro-spinal Nervous System. — This consists of the brain, the spinal cord, and the spinal nerves.

The Brain. — There are two main parts of the brain, the cerebrum, which fills all the upper part of the cranium, and the cerebellum, very much smaller, in the lower back part of the cranium. The cerebrum is divided into right and left hemispheres by a lengthwise groove. The surface of the cerebrum is covered with ridges called convolutions. The outside of the brain is of gray matter, consisting of cells, while the inside is white, consisting of nerve fibers.

Fig. 23. The Cerebro-spinal Nervous System.

Two Functions of the Brain. — Only two functions of the brain are to be noticed now. One is *sensation*, the other *motion*, or rather the control of motion. Nerve currents that come to the brain, produce all our sensations. Sen-

sation is in the gray matter on the outside of the brain. When we wish to move any part of the body, the first thing is to *will* to do it. This action is also in the gray matter on the outside of the brain, but in different parts from those which have sensation. The act of *willing* to do anything sends nerve currents, or impulses, along nerve fibers to the part that is to be set to work. The white fibers of the inside of the brain connect the cells of the gray matter with the various parts of the body through the base of the brain, the spinal cord, and the spinal nerves.

The Spinal Cord. — The spinal cord is a cylindrical body extending from the brain along the cavity of the spinal column. Its diameter is not uniform throughout. Between the shoulders is an enlargement called the cervical enlargement, where the large nerves are given off to the arms. In the region of the loins is the lumbar enlargement, where the nerves are given off to supply the legs. The outside of the cord is white, but the central portion consists of gray matter. The white portion is made up of fibers, but the gray matter consists of nerve cells as well.

The Spinal Nerves. — These are given off in pairs from the sides of the spinal cord. They pass out through notches between the successive vertebras, so there is no danger of their being crushed, or even pinched, when the backbone bends. In the regions of the shoulders and loins the spinal nerves are large, as they supply the large muscles of the limbs; but in the middle of the back, where only the muscles of the body wall are supplied, the nerves are small. We have thirty-one pairs of spinal nerves.

The Roots of the Spinal Nerves. — Each spinal nerve arises by two roots, one nearer the back, called the *dorsal*

root, the other nearer the ventral surface, the *ventral* root. These two roots soon unite to form one spinal nerve.

Structure of Nerves. — If we trace a nerve outward, we find that it is continually subdividing. This division continues until the branches are too small to be seen by the naked eye. Microscopic examination shows that a nerve is made up of a great number of fibers bound together in a common sheath of connective tissue, as is the case with muscle. When the nerve divides, there is ordinarily no true branching or forking, but certain of the fibers simply separate from the rest, as in the separation of the fibers in floss silk.

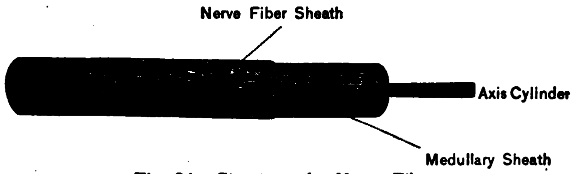


Fig. 24. Structure of a Nerve Fiber.

Structure of a Nerve Fiber. — A single nerve fiber is too small to be seen by the naked eye, being only about one two-thousandth of an inch in diameter. It consists of the following parts: —

1. The *axis cylinder*, a central strand, or core, of semi-transparent, gray material.

2. The *medullary sheath* is a layer of white, oily material around the axis cylinder.

3. The *nerve fiber sheath* is a thin, transparent outer sheath of connective tissue.

Function of Nerve Fibers. — The only function of the nerve fiber is to convey nerve impulses. The nerve impulse passes along the axis cylinder as an electric current passes along an insulated wire.

Afferent and Efferent Nerve Fibers. — Nerve fibers that carry impulses toward the spinal cord or brain are called *afferent* nerve fibers. Fibers that convey impulses from the brain or spinal cord are *efferent* nerve fibers.

Cross-section of the Spinal Cord. — If a thin slice of the spinal cord be made as shown in Fig. 25, it will be seen that the central part is darker in color than the outer part. The central part is known as the gray matter, in distinction from the rest, which is called the white matter.

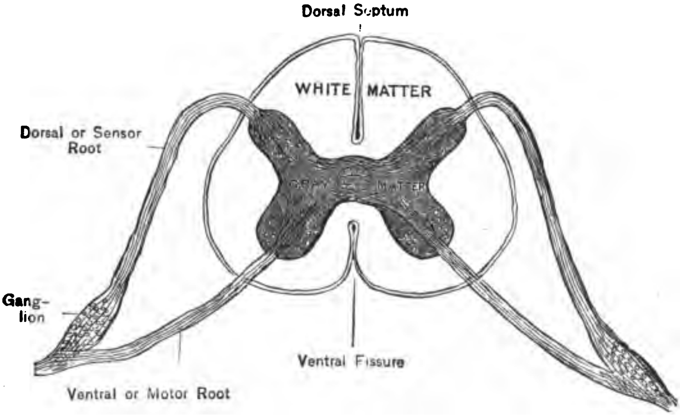


Fig. 25. Cross-section of Spinal Cord.

The white matter of the nervous system is made up of nerve fibers, whose structure and use we have just considered. But the gray matter has a different structure and a different function. Instead of being made up mainly of fibers, it is composed of cells, one of the forms of which is represented in Fig. 26. Some of the branches of these cells are continued, and become the axis cylinders of nerves, and it is believed that every nerve fiber begins as a branch of some nerve cell.

Functions of the Spinal Cord. — The spinal cord has two main functions: —

1. Its conducting power, by means of the white fibers which make up the outer part of the cord. These fibers connect the gray matter of the brain with all parts of the body, and carry messages to and from the brain.

2. The gray matter is the center of the reflex actions of the cord.

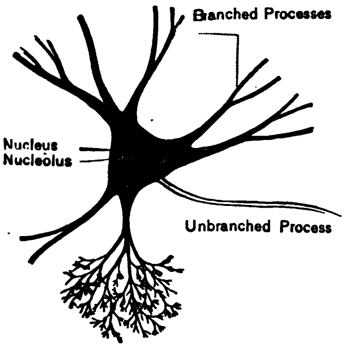


Fig. 26. A Large Nerve Cell from the Gray Matter of the Spinal Cord.

Ganglions. — Masses of nerve cells make up nerve centers, or ganglions, such as are on the dorsal roots of the spinal nerves. These also would show under the microscope that their chief constituent is a collection of nerve cells which give off one or more branches. The gray matter of the spinal cord is a collection of ganglions.

Reflex Action in a Sleeping Child. — If the sole of the foot of a sleeping child is gently tickled, the foot will be drawn up. The child has no sensation. The brain has nothing to do with it. It is purely reflex action. A nerve impulse has gone to the spinal cord, and another impulse has been sent out to make the needed movement. But sometimes the child may be half awake and the foot might be drawn up by voluntary action. Let us take another case, with which nearly every one is familiar, to show that the brain has nothing to do with reflex action.

A Hen with its Head cut off. — Nearly everybody knows that after a hen's head is cut off, it "flops" around for some time, and that frequently when one takes hold of its feet to pick it up, it begins to struggle. Now this also is reflex action of the spinal cord. And there can be no doubt that the brain has nothing whatever to do with it.

The Gray Matter of the Cord the Center of Reflex Action. — In reflex action the current runs up the nerve to the spinal cord. The gray matter of the central part of

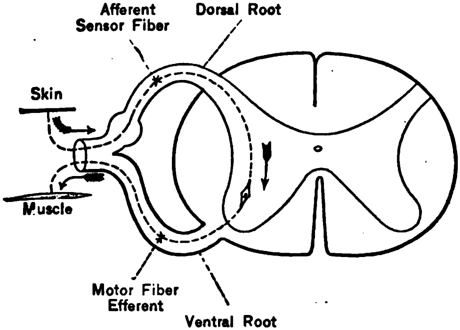


Fig. 27. Diagram of Reflex Action of the Spinal Cord. (After Landois and Stirling.)

the cord receives the message, and sends back a nerve impulse to the muscles, to make them shorten and pull the foot away from the source of irritation.

The Parts Essential to Reflex Action of the Spinal Cord: — 1. A sensitive surface (the skin, for instance). 2. Afferent nerve fibers. 3. A nerve cell, or cells, in the center of the spinal cord. 4. Efferent nerve fibers. 5. Working organ, as muscle or gland.

Steps in Reflex Action. — In the above examples the steps in order are: —

1. Stimulation of the nerve endings in the skin of the foot. 2. Passage of nerve impulses up the afferent fibers to the spinal cord. 3. Reception of the impulse by cells of the gray matter in the cord. 4. Sending back nerve impulses. 5. Along efferent fibers to 6. Muscles which shorten so as to move the foot.

Importance of Reflex Action. — It is important that we understand the nature of reflex action, for very many of the processes of the body are regulated by it. Not only such motions as winking when anything comes quickly

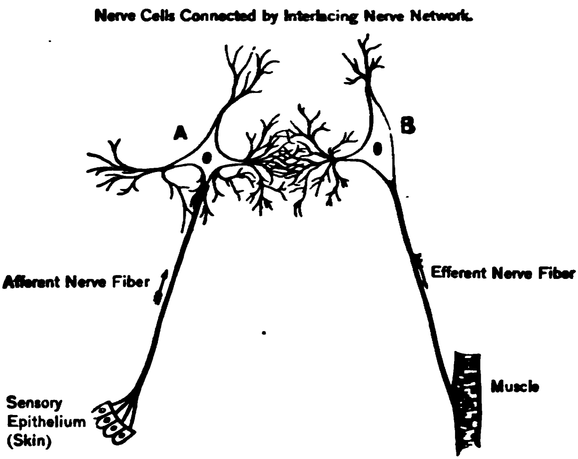


Fig. 28. Parts used in Reflex Action.

toward the eye, dodging, jumping when suddenly touched by anything hot or when pricked by a pin, but also the regulation of circulation, respiration, and digestion, are brought about through reflex action.

Destination of Nerve Fibers. — The sciatic nerve (the large nerve of the thigh, see Fig. 23) is composed of many fibers. If this nerve is traced outward, it is found to be continually subdividing and sending smaller branches to the muscles, and finally in the muscles one fine nerve fiber goes to each muscle fiber. (See Fig. 13.) Many fibers go on past the muscles to the skin. We can feel in any part of the skin, and we can tell just where we are touched.

These fibers from the skin carry nerve impulses inward, as those going to the muscles carry impulses outward.

Nerve Roots and their Functions. — Observations made on animals, and accidents in the case of man, show that all the fibers of the nerves that carry currents to the muscles pass out from the spinal cord into the ventral root, and that all the fibers that carry currents inward enter the spinal cord through the dorsal root. Hence, the dorsal root is often called the afferent root, and the ventral the efferent root. Since ingoing impulses produce sensation, the dorsal root is called the sensory root, while the ventral root, carrying currents outward to produce motion, is called the motor root.

Effect of Stimulating a Spinal Nerve. — Experiments have shown that if, in an uninjured animal, a nerve, or more properly a nerve trunk — as the sciatic nerve — be stimulated, for instance, by an electric shock, two effects are produced: first, motion in the parts whose muscles are supplied by the nerve; second, sensation, which is referred to the parts of the skin supplied by the branches of the nerve. This double effect is because both sets of fibers in the nerve have been stimulated, one set carrying currents inward, the other outward.

Cramp. — Cramp is a spasmodic shortening of the muscles, attended with pain.

Tetanus. — Tetanus (or locked jaw) is a spasmodic and continuous shortening of the muscles, causing rigidity of the parts they supply. It is due to the disordered and excessive stimulation of the muscles through the nerves.

Crossing of the Fibers from the Brain to the Spinal Cord. — Both the brain and the spinal cord consist of two lateral halves connected by cross fibers. Each half of the

brain is connected with the opposite half of the body. This is accomplished by the crossing of the fibers. The fibers that carry nerve impulses outward cross as they leave the brain, at the very beginning of the spinal cord, in the part known as the spinal bulb. The sensations arising from touching anything with the right hand, therefore, are in the left half of the brain, and the right half of the brain controls the left hand.

Nervous System compared to a Telegraph System. — It is convenient to compare the nervous system to a telegraph system. Nerve impulses pass along the nerve fibers as electric currents travel along the wires. The ganglions, which receive and send impulses, are similar to the offices which receive and send out electric currents. But there is one important difference: in telegraphing, the same wire is used, both for sending and receiving messages; while in the nervous system there are two sets of fibers, one for incoming impulses and another for outgoing impulses.

Harmony in Muscle Action. — In throwing a stone a number of muscles are used. Each muscle shortens under the influence of a nerve impulse started by the brain and brought by a motor nerve. If any muscle shortens too soon, or a little too strongly, the stone goes to one side. In a tune on a piano we know that the right keys must be struck at the right time, and with the proper force. What the player is to the instrument, the brain is to the body.

Temporary Loss of Muscular Power. — It may have happened that after sitting long in one position you attempted to stand, but could not. One leg failed to act at the bidding of your will. When the foot is "asleep" we get little sensation from it; we hardly know whether it is touching the floor. Pressing on it with the other foot causes no pain.

The brain starts the nerve currents, and they run along the nerve as far as the compressed part; here they stop. On account of external pressure the nerve has temporarily lost its power of conducting nerve currents. They cannot reach the muscles of the leg below. Hence the muscles do not shorten, and we do not rise, no matter how strongly we will to do so.

Dependence of Nerves and Muscles. — But what beside the nerve has been compressed? What process in the limb has been interfered with by the pressure due to the position in which one has been sitting or lying? What is the temperature of the benumbed limb?

On what are the nerves and muscles so dependent for keeping up their activity?

Summary. — 1. Motions are voluntary or involuntary, but all are under control of the nervous system.

2. The cerebro-spinal nervous system consists of the brain, the spinal cord, and the spinal nerves.

3. Each spinal nerve has two roots: the dorsal, which is afferent and sensory; the ventral, which is efferent and motor.

4. A ganglion is a nerve center largely composed of nerve cells.

5. Nerves are made up of nerve fibers.

6. A nerve fiber consists of the central core (or axis cylinder), which conducts the nerve impulse, the medullary sheath, and, outside, the nerve-fiber sheath.

7. The spinal cord has in its outer part white nerve fibers; in its center, gray nerve cells.

8. These cells are branched, and at least one branch becomes the axis cylinder of a nerve fiber.

9. The gray matter of the cord is the center of the reflex action.

10. The nerve fibers from each half of the brain connect with the opposite half of the body.

11. The nervous system is comparable to a telegraph system.

Questions. — 1. Name as many involuntary motions as you know.

2. What other cases of reflex action do you know?

3. Why is a man partially paralyzed when he has broken his back?

CHAPTER VI.

CIRCULATION OF THE BLOOD.

The Blood and its Work. — There is no bleeding when we trim the nails or cut the hair, and the outer skin has no blood in it. But the inner skin, and almost every tissue within it, if pierced even by the finest needle, yields blood. We know that loss of blood causes weakness, and may soon cause death.

What kind of a substance is blood? Why is it so essential to life? How does it do its work?

The Rate of the Heart Beat. — The heart beats about seventy-two times a minute. In children it beats faster. The rate is increased by exercise, by heat, by food, and by mental excitement.

The Heart Beat and the Pulse. — 1. The heart beat may be felt at the left of the breastbone.

2. The pulse may be felt at the wrist, in the neck beside the windpipe, and in various parts of the body. Perhaps the most convenient place to study it is at the temple. Lay the forefinger lightly along the cheek just in front of the ear. Count the pulsations for a minute.

3. Let one or two pupils step to the blackboard and put down the number of pulsations of each pupil, and divide by the number thus reporting, to get the average.

4. Let all count the pulse while sitting. Get the average of the class.

5. Find the pulse while sitting; rise quickly, and immediately begin to count the pulse. Compare with the pulse as taken while sitting.

6. Compare the pulse before and after meals.

The Shape of the Heart. — The heart is cone-shaped. But the point or apex is down, and the big end, or base, is up, so when we speak of the base of the heart we mean the upper part, not the lower.

The Position of the Heart. — The base of the heart is in the center of the chest, just back of the breastbone, but the apex points downward and to the left (see Figs. 32 and 53).

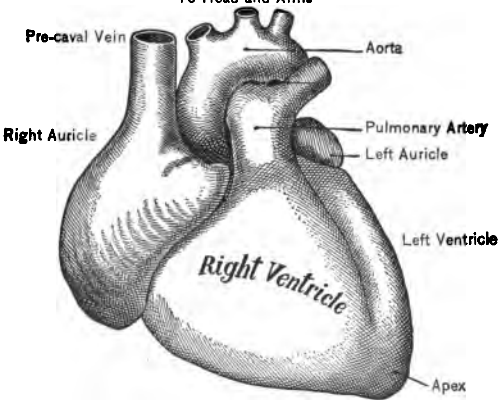


Fig. 29. The Heart, from the front.

The Size of the Heart. — A person's heart is about the size of his clenched hand.

The Covering of the Heart. — The heart is inclosed in a loose-fitting bag, the *pericardium.* Within the pericardium and around the heart is a small quantity of liquid, called the *pericardial fluid.*

The External Features of the Heart. — The larger part of the heart is made up of ventricles, the auricles being two ear-like flaps at the base, one on each side. There is a deep notch between the auricles and the ventricles.

The line of division between the two ventricles is marked by a groove, which runs obliquely along the front surface. In this groove are blood tubes and usually some fat. (See Figs. 29 and 30.)

The Internal Structure of the Heart. — The two halves of the heart are completely separated from one another by a partition. Each half has valves which, part of the time, separate the cavity of each auricle (at the base) from the cavity of the ventricle (at the apex).

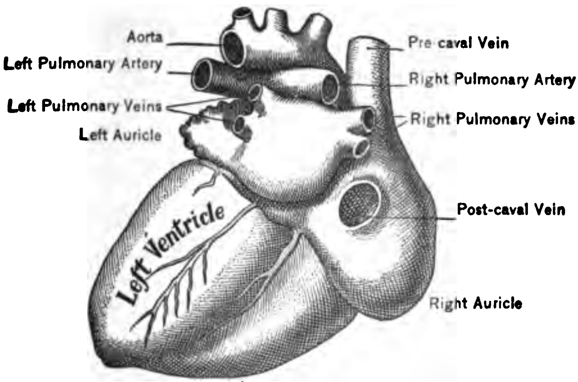


Fig. 30. The Heart, from behind.

The Valves of the Heart. — Between the auricles and the ventricles are curtain-like valves (see Fig. 33), whose upper edges are attached to the inner surface of the walls at the upper margin of the ventricle. These flaps are somewhat triangular, and have strong, white, tendinous cords extending from their edges and under surfaces to the walls of the ventricle below. In the right half of the heart there are three flaps, and this valve is called the tricuspid valve. In the left side there are two flaps, which, together, make up the mitral valve. In the resting heart

these flaps hang down along the walls of the ventricles so that on opening the heart one would see only a single cavity in each half of the heart.

The Aur-vent Valves. — Since these valves are between the auricles and the ventricles they are often called the auriculo-ventricular valves. Nearly every one knows of the town named Pen Mar on the line dividing Pennsylvania from Maryland. The meaning of the name is clear. And any one can tell where Texarkana must be. So for convenience we shorten auriculo-ventricular to *aur-vent*, and when speaking of the aur-vent valves we know, without having to stop and think, that they are between the auricles and ventricles.

The Semilunar Valves. — From the base of the right ventricle arises the pulmonary artery. Within its base, just as it leaves the ventricle, are three pocket-like valves, like "patch-pockets." They are in a circle, with their edges touching, and thus surround the opening, with their mouths opening away from the heart. A similar set of valves are within the base of the aorta, which arises from the left ventricle. Both these sets of valves are called semilunar valves. As they are between the ventricles and the arteries they are sometimes called the ventriculo-arterial valves. And this may be shortened to *vent-art* valves. (See Fig. 33.)

Dissection of the Heart. — No description (or even pictures) can give a clear idea of the heart. A good model will be of some assistance. But the heart itself should be examined carefully and then dissected. The heart and lungs of a sheep should be obtained (ask the butcher to save the "pluck," *i.e.* the heart and lungs taken out together). The relations of the heart to the lungs and other organs should first be studied, and then the pericardium opened. Observe the outside of the heart, and then cut the heart open to see the points given in the

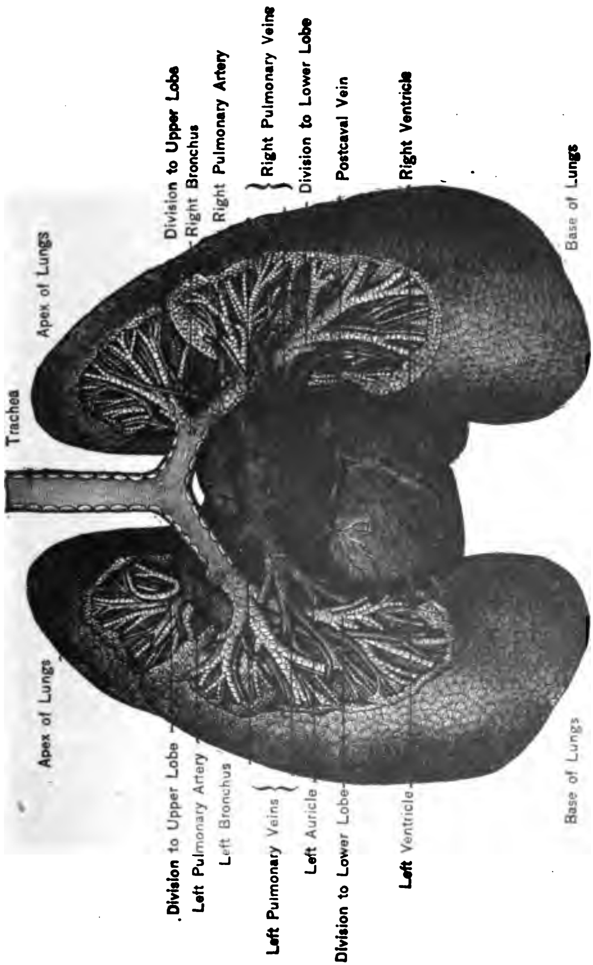


Fig. 31. Back View of Heart and Lungs.

above description. After the heart is severed from the lungs the auricles may be cut off; then, by pouring water into the ventricle, the action of the valves between the auricles and the ventricles will be seen. Pressing on the outer surface of the right ventricle will make the water escape through the pulmonary artery. If this be split open, the semilunar valves at its base may be found.

The Blood Tubes connecting the Heart with Other Organs. — The aorta arises from the left ventricle. The pulmonary artery springs from the right ventricle and sends blood to the lungs. The pre-caval and the post-caval veins enter the right auricle. The pulmonary veins, two from each lung, enter the left auricle. (See Figs. 31 and 32.)

The Aorta. — The aorta is the largest artery in the body. It arises from the base of the left ventricle and runs a short distance toward the head, then it arches over and runs toward the lower part of the body. The bend, above the heart, is called the *arch* of the aorta. At the arch branches are given off which supply the right and left arms, and the right and left sides of the head. Beyond the arch the aorta passes behind the heart and runs along the backbone and passes through the diaphragm. Just beyond the diaphragm it gives off branches to the liver, stomach, intestine, pancreas, and spleen. It gives a branch to each kidney, and finally divides into two large branches to the lower limbs. Numerous small branches are sent to other organs; in short, the aorta supplies blood to every organ of the body except the lungs. (See Figs. 29, 30, and 32.)

The Caval Veins. — There are two caval veins, the pre-caval and the post-caval. The pre-caval brings the dark blood from the head and arms. It has four main branches, one from each side of the neck, the jugular veins; and one from each arm, the subclavian veins. These four

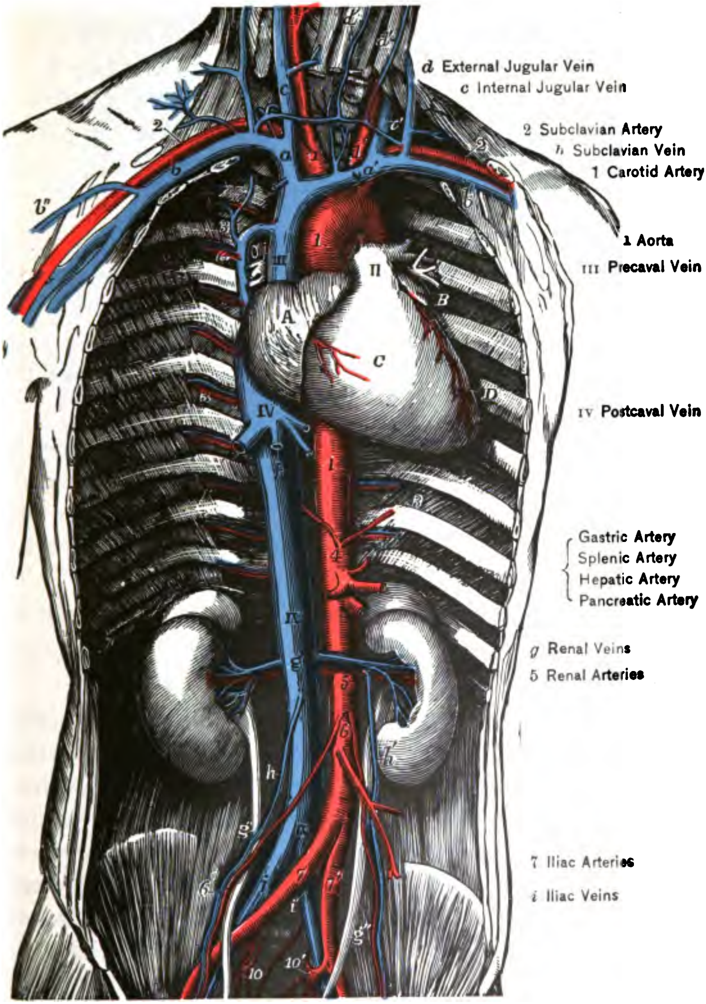


Fig. 32. Distribution of Arteries and Veins.

unite to form the pre-caval vein, which runs downward and enters the right auricle. The post-caval vein begins in the lower part of the abdomen, by the union of the two large veins from the lower limbs. As it runs upward, it receives branches from the kidneys and from the liver; it passes through the diaphragm and enters the right auricle. (See Figs. 29, 30, and 32.)

The Distribution of the Arteries and Veins. — The organs of the body receive a supply of blood in proportion to their size and activity. The artery supplying the blood to any organ and the vein which returns it usually lie side by side (see Fig. 32). The larger arteries are usually deep-seated and in protected places.

The Action of the Heart. — The heart consists of muscle fibers so arranged that they form a thick-walled bag, which stands expanded when the muscles relax. But when the fibers shorten, the heart contracts and the blood is forced out.

The complete action of the heart consists of three parts, — the contraction of the auricles, the contraction of the ventricles, and the pause.

The Pause. — During the pause the blood is steadily pouring into the auricles; into the right auricle from the caval veins, into the left auricle from the pulmonary veins. The aur-vent valves are now open, and their flaps hang loosely beside the walls of the ventricles. The blood, therefore, instead of stopping in the auricles, passes on into the ventricles. As the ventricle fills, the aur-vent valves float up, as seen in the experiment of pouring water into the ventricle. (See right-hand part of Fig. 33.)

The Contraction of the Auricle. — When the ventricle is full, but not stretched, and the auricle partly full, the auricle

suddenly contracts, thus forcing more blood into the ventricle, and distending it. At the same time the aur-vent valves, which were already nearly closed, are tightly closed by the pressure of the blood which is forced up behind them. The flaps of the valves are kept from going up too far by the tendinous cords and by the muscles to which the cords are attached.

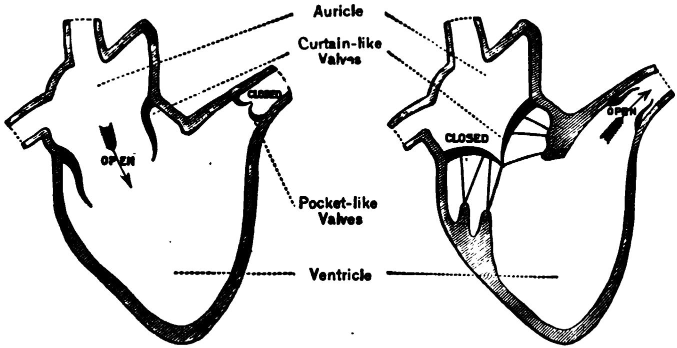


Fig. 33. Diagram of the Heart, showing the Action of the Valves.

The Contraction of the Ventricle.—Next comes the contraction of the ventricle, slower, but more powerful than that of the auricle. As the walls of the ventricle are drawn together, they press upon the blood. It cannot go back into the auricles, for the more it presses against the aur-vent valves, the more tightly they are closed. The vent-art (semilunar) valves are closed by back pressure in the aorta and pulmonary artery. But the pressure of the blood in the ventricles is so much greater that the vent-art valves are forced open, and the blood is driven out of the ventricles; from the right ventricle into the pulmonary artery, and from the left ventricle into the aorta.

While the ventricles are contracting and forcing their

blood out, the auricles are slowly filling by the steady inflow through the veins.

Systole and Diastole.—The contraction of the heart is called the *systole*, and its dilation is the *diastole*.

Dilation of the Ventricle.—As soon as the ventricle has completed its contraction it dilates, and most of the blood that has accumulated in the auricle simply falls into the ventricle. The dilating ventricle makes a slight suction, so the blood is in part drawn into the ventricle. During the remainder of the pause the blood accumulates in the ventricle and auricle till the auricle again contracts and the action is repeated. This is true of both halves of the heart, which work at the same time, the two auricles contracting together, and then the two ventricles. The right heart pumps dark blood while the left heart pumps bright blood. The left ventricle is thicker walled and stronger than the right.

Work and Rest of the Heart.—Immediately after the contraction of the auricle comes the contraction of the ventricle. The pause is as long as the contractions of the auricle and ventricle put together. In other words, the heart is resting half the time. It is often said that the heart never rests. Its periods of work and rest are so short and follow each other in such rapid succession that it is hard for us to realize that there is a resting time between each two beats, and that this resting time is as long as the working time.

Overworking the Heart.—During violent exercise the heart is likely to be overworked trying to pump blood enough to supply the overworked muscles. One very important part of training an athlete is to strengthen the

heart by regular exercise so it will not tire out in pumping the blood to the muscles during an athletic contest, such as a foot race or boat race.

The Work of the Auricle. — The auricle has three functions: (1) to complete the filling of the ventricle; (2) to complete the closing of the aur-vent valves; (3) to act as a reservoir for the blood entering the auricle while the ventricle is contracting, that is, while the aur-vent valves are closed.

The Work of the Ventricle. — The contraction of each ventricle forces the blood around to the ventricle of the other side of the heart.

The Sounds of the Heart. — There are two sounds of the heart: —

1. A short, sharp sound made by the closing of the semilunar valves.

2. Just preceding this sound a longer, duller sound may be heard during the contraction of the ventricles. This is supposed to be due to the vibrations of the walls of the ventricles and of the aur-vent valves.

Action of the Large Arteries. — The arteries have elastic tissue in their walls. When the blood is forced into them, they are stretched. As soon as the ventricle ceases to contract, and sends no more blood into the arteries, they "stretch back." We should not say contract, for it is simply an elastic reaction. As the artery reacts it presses on the blood, and hence the blood tries to escape in every possible way. It cannot go back into the ventricles, for it fills the pockets of the semilunar valves, and closes them with a click. The blood therefore flows along the arteries, through the pulmonary artery to the lungs, and through

the aorta and its branches to all the other parts of the body.

The elastic reaction of the arteries thus helps to make steady the flow of blood, which is jerky as it leaves the heart.

Variation of the Amount of Blood needed. — Each organ requires a supply of blood in proportion to its activity. An actively working organ, like the brain, demands much more blood than does such an inactive organ as a bone. Further, the working tissues, such as the brain and muscles, need a great deal more blood while they are at work than when they are resting. An organ needing a large supply of blood all the time might secure this by having a large artery. But how can the supply be regulated so that an organ may receive, now more, now less, according to its needs?

Plain Muscle Fibers in the Walls of the Arteries. — This is regulated by the medium-sized and small arteries leading to the parts. In the walls of these arteries are plain muscle fibers. They are arranged circularly in the walls of the arteries (see Fig. 36). These fibers have, like all muscle fibers, the power of shortening. When they shorten they reduce the size of the artery, and, therefore, for the time, less blood can flow through it. When the muscle fibers relax, the artery widens, and allows more blood to pass through it.

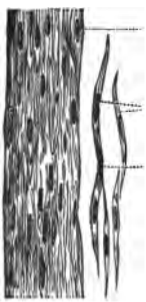


Fig. 34. Plain Muscle Fibers.

Illustration of the Action of Muscles in Arterial Walls. — To illustrate the action of the muscles in the walls of an artery, let the water

run through a hose or large rubber tube. Now, if a row of persons take hold of this tube, the grip of their hands is like that of the muscles.

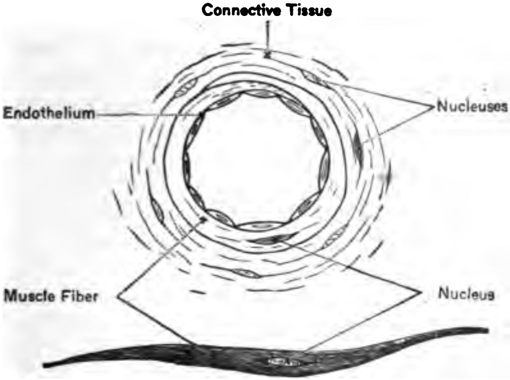


Fig. 35. Plain Muscle Fiber. Separate and in Wall of Artery.

When the hands tighten their grip, the size of the hole in the tube is made smaller, and less water is allowed to flow through it. When the hands relax, the tube, being elastic, allows more liquid to flow through it.

Illustration of a Small Artery. — To represent a small artery, take a small, thin-walled rubber tube and wind a red thread around it. Now, if the thread could shorten, it would make the tube smaller.

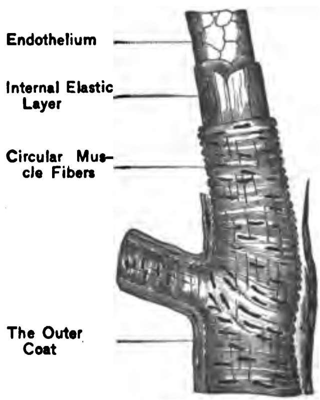


Fig. 36. Coats of a Small Artery.

The Action of Plain and Striated Muscles Fibers compared. — These plain muscle fibers are further like those of the skeletal muscles in that they are under the control of the nerves, but they are involuntary in their action. We cannot interfere with the action of these muscles, no matter how strongly we may will to do so. Without our thinking about it, more blood goes to the muscles of the legs when we walk, more to

the brain when we are studying, to the digestive organs after eating, etc. The plain muscle fibers shorten at a much slower rate than the striated fibers. They are also slower in relaxing.

Fig. 37. "Capillary Blood Tubes in the Web of a Frog's Foot, under a Low Power of a Microscope." From Hall's "Physiology."

Circulation of Blood in the Web of a Frog's Foot.—This is a beautiful sight. Here you may see, under the microscope, the active streams of blood. Small arteries divide to form capillaries, and capillaries unite again to form the small veins. In the narrow capillaries the corpuscles may be seen moving along in single file, with barely width enough to pass through the slender tube. If you see this in the frog's foot, you can understand how the blood flows through all the active tissues of your body. (See Figs. 37 and 39.)

The Blood Flow in the Capillaries. — The arteries divide and subdivide, and become capillaries, which have connecting branches, forming a close network of tiny thin-walled tubes. These penetrate nearly every tissue of the body. The blood cannot do its full work till it is in the tissues, and to reach the tissues it must soak through the walls of the capillaries. The work of the heart and arteries is to keep a slow and steady flow of blood through the capillaries, that the tissues may be constantly supplied.

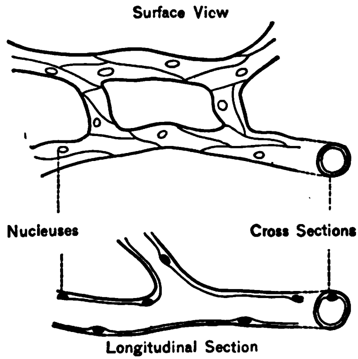


Fig. 38. Capillaries, composed of a Single Layer of Cells.

The Veins.—The capillaries, after penetrating the tissues, unite again to form small veins, which in turn unite to form larger ones, till finally two great veins, the pre-

caval from the upper and post-caval from the lower part of the body, return the blood to the heart. The veins, like

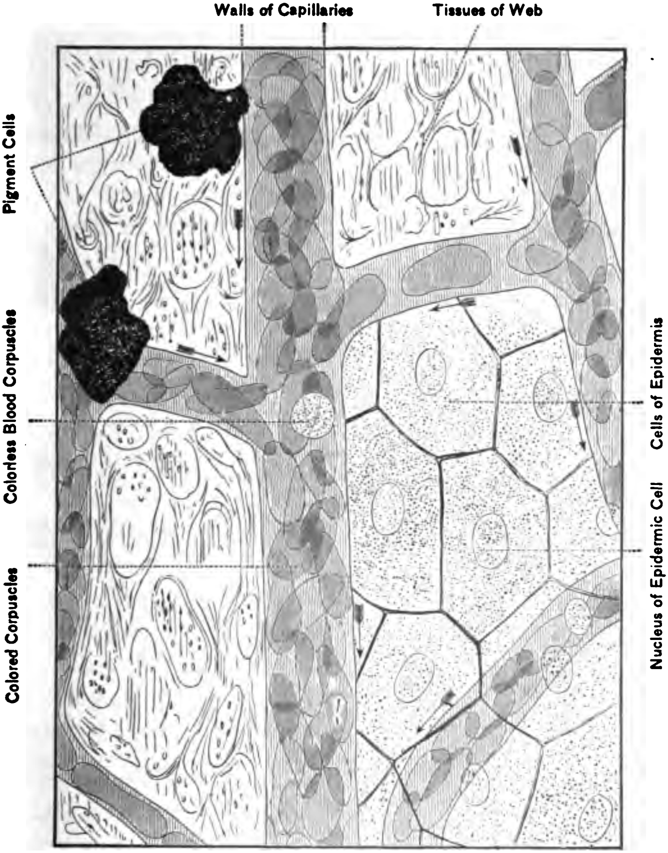


Fig. 39. Part of Frog's Web (highly magnified).

the arteries, are smooth inside and elastic (though less elastic than the arteries). They are thinner-walled than the arteries (see Fig. 40) and collapse when empty,

whereas the larger arteries stand open, after they are emptied of blood. There are many cross-branches uniting veins, so that if the flow is stopped in one vein, the blood can take a "cross-road" into another large vein. This cross-branching may usually be seen on the back of the hand.

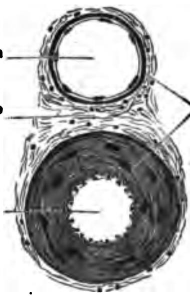


Fig. 40. Cross-section of Small Artery and Vein.

The Valves in the Veins. — The only valves in the arteries are those at the beginning of the aorta and pulmonary artery. Many of the veins have similar pocket-like valves though less strong than those of the arteries. They are usually in pairs, but sometimes single or in threes. They all have the mouths of the pockets toward the heart, so that the blood flows freely toward the heart, but is kept from flowing the other way on account of the filling of the valves by the back pressure of the blood. When the blood is flowing through the veins toward the heart, the valves lie against the walls of the veins (see Fig. 41).

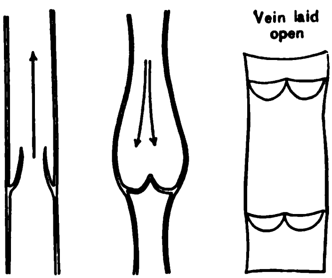


Fig. 41. Valves of the Veins.

Illustration of Valves in the Veins. — Make a cloth tube (or take the lining of a boy's coat sleeve) and sew three patch-pockets on the inside, in a circle, *i.e.* with edges touching each other. Make the pockets a little "full." Pour sand, shot, or grain through the sleeve first in one direction and then in the other. This shows how the valves fill and block the passage when there is back pressure of the blood.

Evidences of Valves in Our Veins. — 1. With the forefinger stroke one of the veins on the hand or wrist toward the tips of the fingers. The veins swell out. The blood meets resistance in the valves of the vein. Their location may be determined by their bulging out during the experiment.

2. Stroke a vein toward the body, and the blood is pushed along without resistance.

3. Let the left hand hang by the side. Note the large vein along the thumb side of the wrist. Place the tip of the second finger on this vein just above the base of the thumb. Now, while pressing firmly with the tip of the second finger, let the forefinger, with moderate pressure, stroke the vein up the wrist. It may be seen that the blood is pushed on freely, but comes back only part way. It stops where it reaches the valves, filling the vein full to this point, but leaving it collapsed beyond, as shown by the groove. Remove the second finger, and the vein immediately fills from the side nearer the tip of the fingers.

These experiments show that the blood in the veins moves freely toward the body, but cannot flow outward to the extremities.

Effect of Pressure on the Veins. — Since the valves in the veins open toward the heart, any alternating pressure on the veins helps to push the blood on toward the heart. The valves are most numerous in the veins near the surface and in the veins of the muscles. The pressure of the muscles during their action (thickening while shortening) produces pressure on the veins; and as the muscles act for a short time only, and then relax, this alternate compression and release aids very much in moving the blood on toward the heart.

How the Muscles help the Heart. — This effect is greater at the time the muscles need the most active circulation; namely, when they are in action, and are using the most blood. The heart has power enough to pump the blood clear around from each ventricle to the auricle of the other side of the heart; but this outside aid comes in good play to relieve the heart at a time when it has an unusual

amount of work to do, as when one is using a large number of muscles vigorously.

"Every active muscle is a throbbing heart, squeezing its blood tubes empty while in motion, and relaxing so as to allow them to fill up anew."

Rate of Blood Flow in the Arteries and Capillaries. — The blood flows rapidly in the arteries, slowly in the capillaries. Why is this? When an artery divides, the two branches taken together are larger than the one artery that divided to form them. Hence as the blood flows on it is continually entering a wider and wider channel; for if all the capillaries fed by the aorta were united they would make a tube several hundred times as large as the aorta.

The Flow of the Blood compared with the Current of a Stream. — If we walk along a stream, we see that the channel keeps changing in width and depth. Where the channel is large, whether from increased width or depth, there the current is slower, but wherever the channel is reduced, the current is more rapid. So the stream in the comparatively narrow artery is swift. In the capillaries, although any single channel is small, these channels all together are wide; the result is the same whether a river widens out into a single lake, or divides into a great number of channels running past many islands.

The Flow of Blood in the Veins. — When two veins unite, the one vein they form is not quite equal to the sum of the two; so when the blood gathers in the veins it is really entering a narrower channel, and it flows faster. And it keeps gaining in speed till it reaches the heart.

Flow in Arteries and Veins compared. — Although the blood keeps flowing fast as it gets nearer the heart in the

caval veins, it does not go as fast as when it left the heart in the aorta, for there are two caval veins each about as large as the aorta.

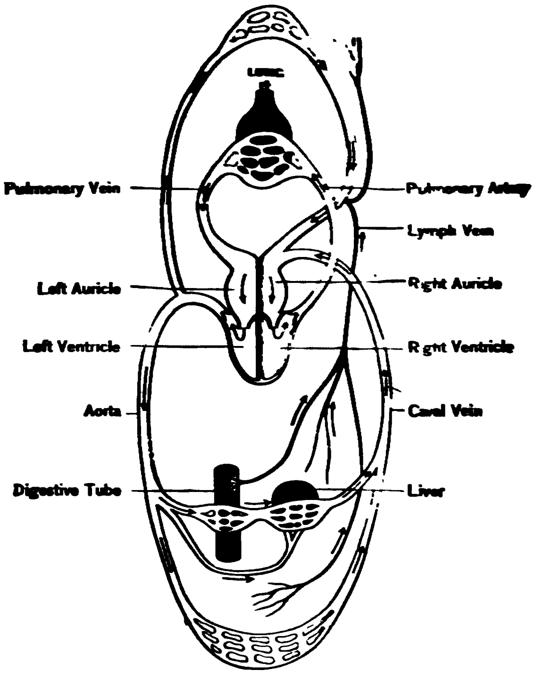


Fig. 42. Plan of Circulation. (Back View.)

Rate of Flow in Arteries, Capillaries, and Veins. — The blood flows rapidly in the arteries, slower in the veins, and slowest in the capillaries.

Summary. — 1. The heart beats about seventy-two times a minute.

2. The pulse is a wave running along an artery.

3. The pulse varies with age, health, food, etc.

4. The heart has two main cavities, one in each half of the heart, and two separate streams are flowing through it.

5. Valves allow the blood to flow through the heart in one direction, but prevent its return.

6. The heart is a hollow muscle, and by contraction forces the blood out into the arteries.

7. The heart works about half the time.

8. The large arteries, by elastic reaction, push the blood on while the heart is resting.

9. Circular muscle fibers in the walls of the medium-sized arteries regulate the blood supply to the organs.

10. In the arteries the blood flow is rapid and jerky, in the capillaries slow and steady.

11. The thin walls of the capillaries allow the liquid part of the blood to soak out and nourish the tissues, and to soak back into the capillaries bearing waste matter.

12. The veins are thin walled, and collapse when empty, while the arteries are thick walled, and stand open when empty of blood.

13. Arteries carry blood *from* the heart, while veins carry it *toward* the heart.

14. The veins have valves which allow the blood to pass toward the heart, but not away from it.

15. Any alternating pressure on the veins aids the blood flow.

16. The blood flow is most rapid in the arteries, slower in the veins, slowest in the capillaries.

17. Gravity influences circulation.

Questions. — 1. Why do the large arteries lie deep?

2. In which direction should the limbs be stroked to aid circulation?

3. How does slapping the hands around the body warm the fingers?

4. How can a horse or a cow be comfortable with the head down?

5. Why are the walls of the left ventricle thicker than those of the right?

6. Trace a drop of blood from the tip of a finger around the circuit to the same point again.

7. Does the pulse at the wrist occur at exactly the same time as at the temple? Or at the same time as the heart-beat?

CHAPTER VII.

CONTROL OF CIRCULATION.

Circulation controlled by the Nervous System. — We know that fear often causes the face to turn pale and that shame makes it red. Certain emotions also quicken or retard the action of the heart. Great grief or joy has caused sudden death by stopping the action of the heart.

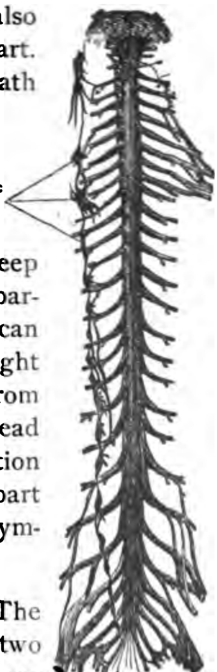


Fig. 43. Front View of Spinal Cord with Sympathetic Ganglions of One Side.

Nervous Control Involuntary. — But this control is not voluntary. The will has nothing directly to do with it. We often wish to keep from getting red in the face when embarrassed, but cannot prevent it. Neither can we keep from turning pale through fright or pain. We cannot keep the heart from beating faster when we are excited. Instead of being controlled by the brain, circulation is chiefly under the control of a special part of the nervous system, known as the Sympathetic Nervous System.

The Sympathetic Nervous System. — The sympathetic nervous system consists of two rows of ganglions in the body cavity, one along each side of the spinal column, receiving branches from the spinal nerves,

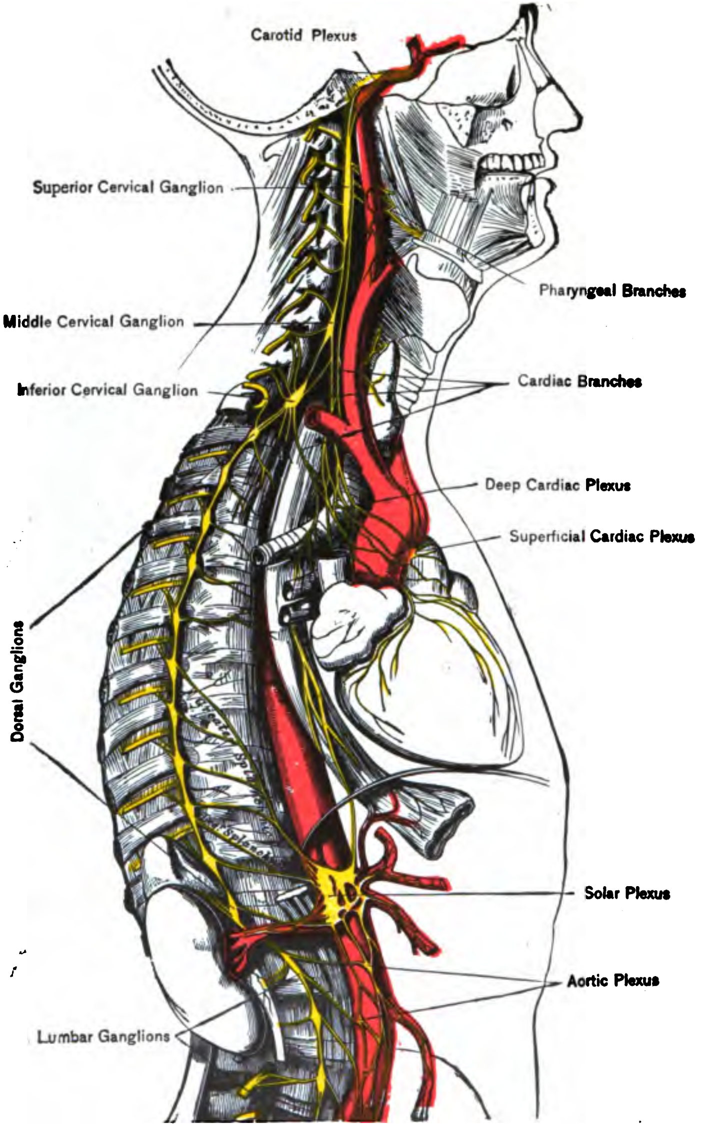


Fig. 44. Vertical Section of Body, showing Sympathetic Nerves and Ganglions of Right Side and their Connection with the Cerebro-spinal Nerves.

and sending branches to the heart and lungs in the chest, and to the liver, stomach, and other organs in the abdomen. In many places these nerves form a thick network called a plexus. One very large plexus on the dorsal surface of the stomach is called the solar plexus. (See Fig. 44.)

Regulation of the Size of the Arteries. — In the last chapter we learned that in the walls of the arteries are muscle fibers having a ring-like arrangement. When these muscle fibers shorten they make the artery narrower, and less blood can flow through it. When the muscle fibers relax, they lengthen; the artery becomes wider, and more blood flows through it. Now these muscle fibers are under the control of the sympathetic nerves. The sympathetic nerves, therefore, regulate the amount of blood that goes to every organ.

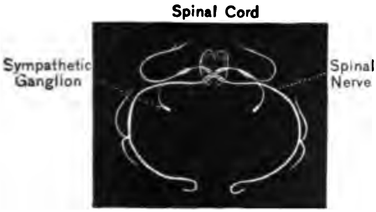


Fig. 45. Ideal Cross-section of the Nervous System. (After Landois and Stirling.)

Blushing. — The sudden reddening of the face means that more blood is flowing through the skin of the face. The arteries by which blood reaches the face have quickly widened, and this is because the muscle fibers in the walls of the arteries have suddenly relaxed. To go still further back in the explanation, some emotion has started nerve currents which travel along the fibers of the sympathetic nerves and caused the arteries to widen.

Sudden Pallor. — On the other hand, if the muscle fibers in the walls of the arteries suddenly shorten, the face will turn pale, because less blood flows in the skin of the face. Such a change, as before, is due to the nerve currents

brought by the sympathetic nerves. Of course the face may turn pale as the result of the stopping, or checking, of the action of the heart, as in ordinary fainting.

Ordinary Changes in Blood Flow.—Without going to the extreme of pallor and blushing, the color of the face varies, under the control of the sympathetic nerves. All the organs of the body receive now more, now less, blood, according as they need it. And all this variation in blood supply is regulated by the sympathetic nervous system.

Effect of Exercise on the Size of the Arteries.—When the muscles work, of course they need more blood. To give them more blood the arteries widen. When one is exercising actively, the muscles take so much blood that we should not expect the brain or the digestive organs to do much work, for there is only a certain amount of blood in the body. Hence if one organ, or set of organs, gets more blood, the other organs must, for the time, receive less. Therefore we see why we should rest after eating, both from muscular as well as from mental work.

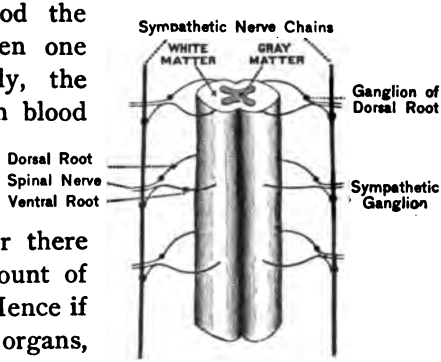


Fig. 46. Relation of Spinal Cord and Sympathetic Nervous System.

How the Heart is made to Beat Faster.—When many large muscles are at work, it is not enough merely to widen the arteries. This would *allow* more blood to go to them, but would not *send* them as much as they need. The heart must beat faster, or with more force, or both. And the heart is made to beat faster and stronger by the nerve

currents that it receives through the sympathetic nerves. When we exercise actively, the fact that the muscles need more blood is telegraphed both to the heart and to the arteries leading to the muscles of the arteries, and they are regulated accordingly.

How the Heart is made to Beat Slower.—The slowing of the beat of the heart is due to other nerves, not belonging to the sympathetic system. The vagus nerves are a pair of cranial nerves. They arise from the sides of the spinal bulb, at the base of the brain, and, passing downward, give branches to the gullet, stomach, lungs, and heart. The distribution of the vagus nerves is shown in Fig. 47. Nerve currents reaching the heart through the vagus nerves make it beat slower, and if the current is strong enough, as in case of a severe blow over the stomach, may, by reflex action, stop the heart.

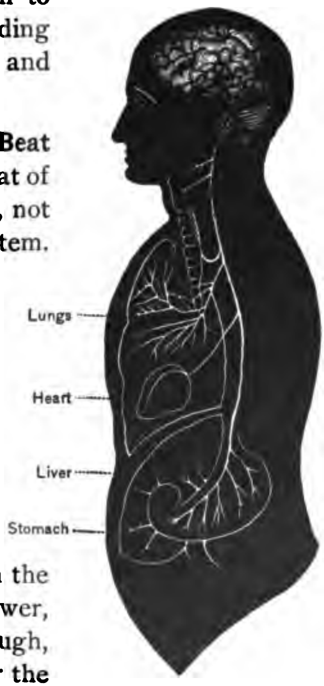


Fig. 47. Distribution of Vagus Nerve.

Influence of Gravity on Circulation.—Although the heart pumps the blood around through the body in spite of the force of gravity, yet the circulation is influenced by this force. For instance, a person who has fainted should be laid flat on his back, that the heart may more easily drive blood to the brain. A sore hand feels less pain if held up, as in a sling, than when hanging by the side, and a sprained

ankle does better rested on a chair, as less blood flows to it. Nearly every one has noted the pain following the pressure of blood when a sore hand, or foot, is suddenly lowered.

Experiments illustrating the Effect of Gravity on Circulation. — Let the pupils stand. Let one arm hang freely by the side. Hold the other arm straight up as far as the clothing will readily permit. Observe: —

1. The difference in the color of the two hands.
2. The difference in fullness, both in the feeling of fullness and in the projection of the veins.
3. The difference in temperature; place the backs of the hands against the cheeks.

The position largely regulates the amount of blood in the hand, and the amount of blood regulates the temperature, the size, and the color.

Clothing and Circulation. — No part of the clothing should be tight enough to interfere with the circulation. Such interference is perhaps most frequent in our foot wear. In cold weather tight shoes keep the feet cold and may result in their freezing, while the same thickness of covering, if loose, would be comfortable. Men often wear hats too tight; this probably leads to baldness. Tight garters sometimes hinder circulation and cause cold feet.

Congestion. — Congestion is an unnatural temporary collection of blood in any part or organ. This may be merely for a short time, and no serious harm results from it. But if it is long continued, it may do great harm.

Inflammation. — If the congestion becomes permanent, we call it inflammation. That is, it is a permanent oversupply of blood, which may bring many bad results. There is usually redness, pain, and often swelling. We have all seen such a condition around a boil or a wound.

Use of Mustard Plaster. — Mustard applied to the skin causes irritation. It makes the skin red. This means that more blood is drawn into the skin through the action of

the sympathetic nerves on the muscles in the walls of the arteries. If there is more blood in the skin, there must be less somewhere else at the same time. Now this is what makes a mustard plaster useful. When there is congestion or inflammation in some internal organ, a mustard plaster applied to the outside draws away some of the blood and thus affords relief to the congested part.

The Hot Foot Bath. — When one has a cold, a hot foot bath relaxes the arteries of the feet. This is a good means of drawing the blood away from internal organs, and often saves the person from serious or even fatal results from a bad cold.

Summary. — 1. Circulation is controlled by the nervous system.

2. This control is involuntary.

3. The sympathetic nervous system consists of two rows of ganglions in the body cavity along each side of the spinal cord.

4. The sympathetic system regulates the size of the arteries, and by this means regulates the amount of blood going to any organ.

5. The heart may be made to beat faster through the sympathetic nervous system. This may come through reflex action and be caused by emotions.

6. The heart may be made to beat slower through the vagus nerves.

Questions. — 1. Why do the feet easily get cold while studying?

2. What makes the hands grow red and puff up after snowballing?

3. Why does light exercise before retiring make one sleep better?

4. How does the application of ice, or cold water, relieve headache?

5. Why should the clothing be changed after getting wet?

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CHAPTER VIII.

THE BLOOD AND THE LYMPH.

The Blood. — The blood is composed of a clear liquid, the plasma, and the blood cells, or corpuscles. In a drop of blood under the microscope the plasma occupies the clear spaces between the corpuscles. The corpuscles make up one third of the bulk of the blood, and the plasma two thirds.

Microscopic Examination of the Blood. — To get a drop of blood from the finger, wind a cord around the finger, beginning at the base, drawing the cord moderately tight, until the last joint is reached. By this time the end of the finger is usually well distended with blood. With a clean needle make a quick, sharp, light puncture near the base of the nail; this ordinarily brings a drop of blood. Put a very small drop on each of several slides and quickly cover with coverslips. Examine with a high power.

The Colored Corpuscles. — These are often called the red corpuscles. Although in the mass they give the blood a red appearance, when seen singly they are faint yellowish red. In shape they are seen to be circular disks, hollowed on each side like a sunken biscuit. These corpuscles tend to gather side by side, in rolls, like coins. Each colored corpuscle is a cell without a nucleus.

The Colorless Corpuscles. — In the open spaces between the rolls of colored corpuscles may occasionally be found some spherical corpuscles. They are often called the white corpuscles. The colorless corpuscles are very numer-

ous around a wound. They seem to help in repairing tissues.

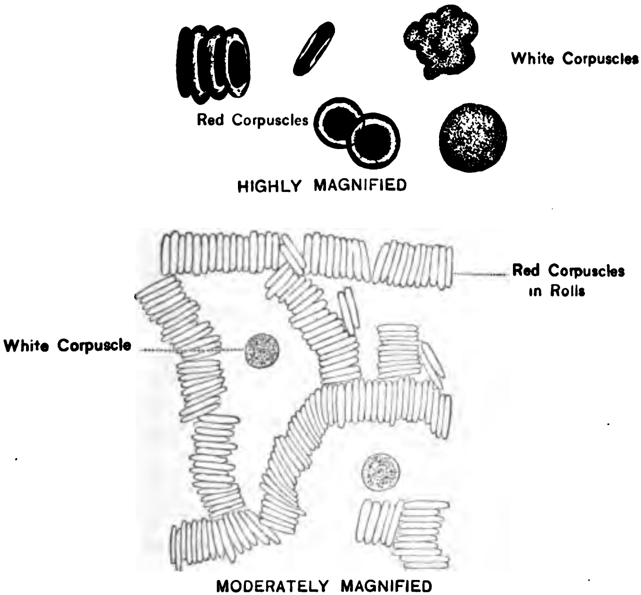


Fig. 48. Red and White Corpuscles of the Blood.

The Plasma. — The plasma consists chiefly of water, having in solution various salts, including common salt; it also contains the nourishing materials for the tissues. These nourishing materials, obtained from the food by digestion, consist chiefly of proteids, fats, and sugar. The plasma also contains waste matters from the working tissues on their way out of the body.

The Color of Blood. — The difference in color of a single corpuscle and the blood in the mass may be better understood by comparing it with something that we see more frequently. A tumbler of currant jelly has a rich, red

color, but a thin layer of the same jelly, as when one takes a spoonful on a plate, has a pale color, more yellowish. The colorless plasma with the colored bodies in it may be compared to a glass dish filled with cranberries and water.

Hemoglobin. — The coloring matter in the blood, then, is wholly in the colored corpuscles. Examination of these corpuscles shows that their color is due to a substance called *hemoglobin.* The hemoglobin in the corpuscles is the chief agent in picking up the oxygen from the air in the lungs and carrying it to the tissues in the body.

The Coagulation of Blood. — When the blood escapes from its natural channels it usually changes from a liquid to a jelly-like condition. This is known as coagulation. It is due to the formation of threads of fibrin from the plasma. These threads of fibrin entangle and inclose the corpuscles, and the two constitute the clot. The liquid that afterward separates from the clot is the serum, and differs from the plasma only in the absence of the fibrin, which is exceedingly small in quantity, though of great importance in its action. Coagulation often serves to stop the flow of blood from wounds.

Fibrin. — If freshly drawn blood be stirred rapidly with a little roll of wire screen, there will soon collect on the wires a stringy substance. Thorough washing will soon leave this colorless. It is fibrin. If the stirring has been done thoroughly, the blood will no longer clot, no matter how long it may stand.

Watching Coagulation. — If you have a slight cut on the hand, it will pay to watch the changes in the blood. First it is a red liquid. Then it becomes jelly-like. Then a clear or yellowish liquid comes out; this is serum. The serum evaporates and the dried clot forms a scab.

Liquid Blood and Coagulated Blood. — The following scheme shows the difference between the liquid blood and the coagulated blood: —

Liquid Blood	Plasma . . .	Serum		Coagulated Blood.
		Fibrin	Clot . .	
	Corpuscles			

"Black-and-blue" Spots. — A bruise often breaks some of the capillaries without breaking the skin. Blood escapes into the spaces in the skin or under it. This blood clots, and the dark color shows through the skin. This clotted blood is gradually absorbed and the color disappears.

Amount of Blood. — The blood constitutes about one thirteenth of the weight of the body. In a body weighing one hundred and fifty pounds this would be about six quarts.

Quantity of Blood in Different Organs. — 1. One fourth is in the heart and the larger arteries and veins (including those of the lungs).

2. One fourth in the liver.
3. One fourth in the skeletal muscles.
4. One fourth in the other organs.

The Lymph Spaces. — We have seen that the capillaries have very thin walls. Through their walls part of the plasma of the blood soaks out, and is then called *lymph*. It passes into irregular cavities in the tissue called *lymph spaces*. Most of these lymph spaces are minute chinks or crevices in the connective tissue of the different parts of the body.

The Lymph Tubes. — Opening out of the lymph spaces are irregular passage-ways called *lymph capillaries*, and

these lymph capillaries are continuous with larger but still thin-walled lymph tubes, called *lymph veins*. But, unlike the blood veins, the lymph veins do not gradually increase in size by uniting. They suddenly form a large tube, the *receptacle of the chyle*, beginning in the upper part of the abdomen. (See Figs. 50 and 81.)

The Main Lymph Duct. — This tube soon narrows and passes through the diaphragm, close to the spinal column, and up along the column near the aorta, and empties into the veins of the neck at the junction of the left jugular and left subclavian veins. This tube is the "thoracic duct," or the *main lymph duct*. It has numerous valves, and, like some of the smaller lymph veins, it presents a beaded appearance, due to the filling and bulging out of the valves. In the right side of the neck is a short right lymph duct, which receives lymph from the right side of the head, neck, and thorax, and from the right arm. The lymph tubes, as a whole, are usually called the "lymphatics." (See Figs. 50 and 81.)

Valves at the Mouth of the Lymph Tubes. — There are valves where these lymph ducts empty into the veins which prevent any reflow of liquid into the ducts, but allow the lymph to pass freely into the veins.

Muscle Fibers in the Walls of the Lymph Tubes. — There are plain muscle fibers in the walls of the lymph ducts.

Lymphatic Glands. — In its course the lymph passes through many kernel-like masses, the lymphatic glands. They may be felt in the armpits, in the groins, and sometimes in the neck. Lymph contains corpuscles which are considered the same as the colorless blood corpuscles. It

is thought that these corpuscles are formed in the lymphatic glands. In a disease called scrofula the lymphatic glands become swollen. (See Figs. 49 and 81.)

The Flow of Lymph. — The flow of lymph is partly due to the blood pressure in the capillaries, this pressure is caused by the heart. In our bodies the flow of lymph is largely aided by any pressure on the lymph veins; for, on account of the valves, as in the blood veins, any pressure must push the liquid toward the heart. Thus the action of the muscles in the limbs, in the chest, in the abdomen, in the movements of breathing, and in the bending of the body, etc., all help in this flow, which is always very much slower than that in the blood veins.

Fig. 49. Lymphatic Tubes of the Surface of the Arm. Lymph Glands at *a*, *b*, *c*, and *d*.

Relations of Blood Flow and Lymph Flow. — While the blood leaves the left ventricle by one tube, the aorta, it returns to the right auricle, not merely by the two caval veins, but a part of the blood (*i.e.* of the liquid part of it) does not return by blood veins, but having left the blood system proper through the thin walls of the capillaries, is brought back by the lymph veins, which, however, join the blood veins just before they empty into the heart. There is only one set of distributing tubes, but there are two sets of collecting or returning tubes.

The Lymph. — Lymph is a clear liquid. It is more watery than the blood plasma, but contains a share of all

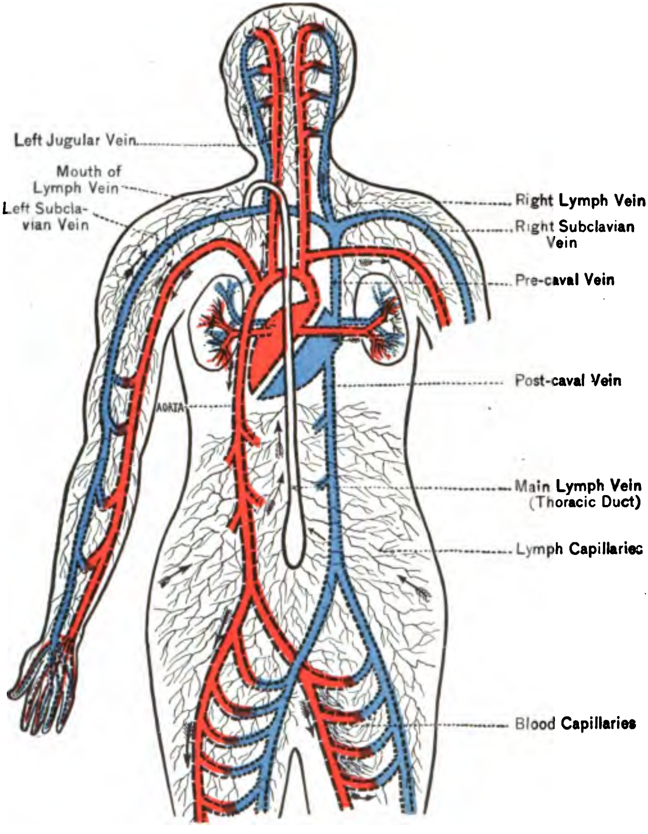


Fig. 50. Diagram of the Circulation of Blood and Lymph (Back View).

its nourishing substances. Lymph may be defined as "*diluted blood minus red corpuscles.*" The blood proper never reaches the tissues.

The Cells of the Body live in Lymph. — The cells of the tissues are bathed in the lymph which fills the spaces in the connective tissue (and there is connective tissue in all the órgans of the body), as water may fill the spaces left between stones built into a wall. The cells get all their nourishment from the lymph, and into the lymph they throw all their waste matter.

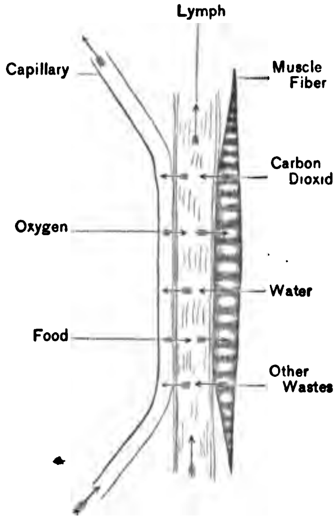


Fig. 51. Relation of Blood and Muscle. (Lymph being Middleman.)

Importance of Lymph. — We can see that the movement and renewal of lymph are as necessary as the circulation of the blood itself; is, in fact, the most important part of it.

Lymph Cavities or Serous Cavities. — We have noticed the pericardial liquid (page 50). There is also a small quantity of similar liquid around the lungs in the pleural cavities, and in the abdominal cavity, around the digestive organs; also in the cavities of the brain. The liquid in each case is lymph, and these cavities, often called serous cavities, are lymph cavities. They communicate with the lymph tubes.

Dropsy. — In health the amount of the liquid in these cavities is small, but in certain disorders it may accumulate. In general, such affections are called "dropsy." The lymph may also accumulate in the tissues of the extremities, causing swelling of the limbs called "dropsy."

Hypodermic Injections. — When it is desirable that a medicine act on the body very quickly, it is sometimes introduced under the skin. This is done by means of a hypodermic syringe, which is a syringe with a slender, needle-shaped nozzle. By means of this the medicine is injected into the tissues under the skin. Here it is taken up by the lymph and is quickly carried through the system and acts on the cells of the body. If the same medicine were taken into the stomach, it would require some time for it to be absorbed and carried into the tissues. Hence time is gained. We can see how much advantage there is in this way of giving medicine when the physician wishes to stop severe pain.

The Spleen. — The spleen is a flattish red body at the left end of the stomach. There is an active circulation of blood in it, and it is supposed to form the colored blood corpuscles. It is often called a blood gland.

Summary. — 1. The blood consists of a liquid, the plasma, in which float the colored and colorless corpuscles.

2. The color of blood is given by a substance, called hemoglobin, in the colored corpuscles.

3. When blood is shed it coagulates, tending to check its own escape.

4. Lymph is like the blood diluted and lacking the colored corpuscles.

5. A set of lymph tubes conveys the lymph into the veins to join the flow toward the heart.

6. In its course the lymph passes through the lymphatic glands.

Questions. — 1. What is blood poisoning?

2. Which is heavier, blood or water?

3. Does it help a sick person to bleed him?

4. What is meant by good blood? Bad blood?

5. What is meant by good humored? Bad humored?

6. Does the blood remain the same from day to day? Or even from hour to hour?

CHAPTER IX.

EXTERNAL RESPIRATION.

The Close Relation between Circulation and Respiration. — Is it not a very striking fact that we breathe once for every four heart beats? And that whatever quickens the breathing also quickens the heart so that the two always keep in almost the same ratio? Let us try to learn why this is so.

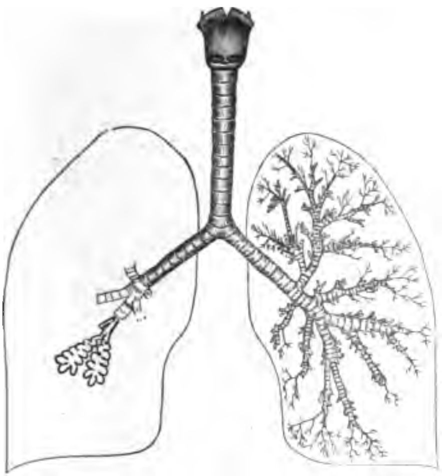
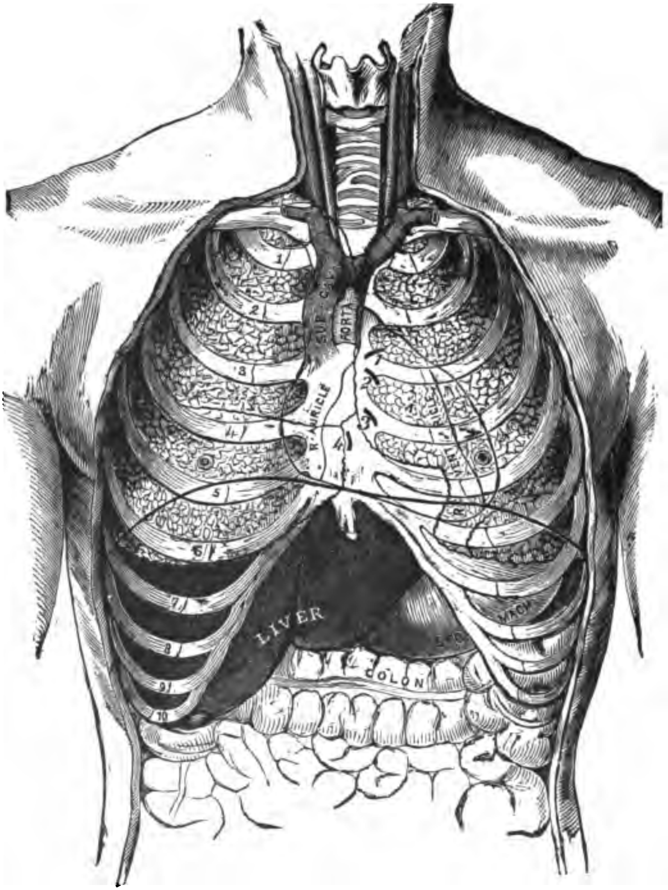


Fig. 52. The Trachea and Bronchial Tubes, showing Two Clusters of Air Sacs.

The Organs of Respiration. — 1. The lungs and air tubes. 2. The organs which increase and diminish the size of the chest, chief among which are the diaphragm and the muscles acting on the ribs.

External Features of the Lungs. — The lungs are of a pinkish color; they are very elastic, soft, smooth, and moist.

The Air Tubes. — The windpipe, or trachea, has in its walls rings of gristle or cartilage, which keep the tube always open. These rings of cartilage are not complete



1. Pulmonary Orifice
2. Aortic Orifice
3. Left Auriculo-Ventricular Orifice
4. Right Auriculo-Ventricular Orifice

The heavy black line between the heart and the liver represents the diaphragm.

Fig. 53. Front View of the Thorax. The Ribs and Breastbone are represented in Relation to the Lungs, Heart, and other Internal Organs.

rings, but are C-shaped. As the windpipe branches (*bronchi*) into the two lungs, the cartilages continue in the smaller branches which extend into every part of the lungs.

The Internal Structure of the Lungs. — The lungs are full of small cavities, like a loaf of light bread. The small cavities are called air sacs or air vesicles, and each air sac communicates with the end of one of the branches of an air tube, through which air comes into and goes out of every air sac. The air sacs are very thin walled, and around the sacs are networks of the fine blood tubes called capillaries.

Elastic Tissue in the Lungs. — The air sacs and air tubes and their surrounding blood tubes are bound together by elastic tissue, which fills up most of the space between them.

The Mucous Membrane. — The lining of the trachea is a mucous membrane. It pours out on its surface a substance somewhat like white of egg, called mucus. This keeps the air moist, and catches particles of dust that are in the inspired air. There is a constant slow current of mucus toward the throat, whence it is, from time to time, hawked up.

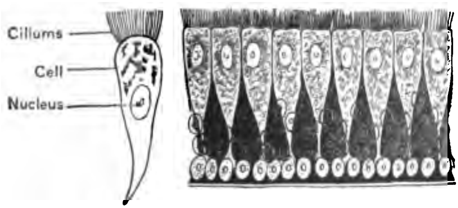


Fig. 54. Ciliated Cells lining the Air Tubes (× 300).

Ciliums. — This current of mucus is caused by the ciliums projecting from the lining cells of the trachea. They are little hairlike projections, in countless numbers, like a field of grass, each cilium having the power of bending back and forth, making a quick stroke toward the throat, then a slower recover stroke. Thus the united wavelike

action of the myriads of lashing ciliums paddles the mucus headward.

The Pleura. — The outside of each lung is covered by a thin membrane, the pleura, which completely surrounds it, except at the root of the lung, where the bronchus and blood tubes enter. Here the pleura turns toward and becomes attached to the inner wall of the chest, forming its lining (still called the pleura), and below passes over

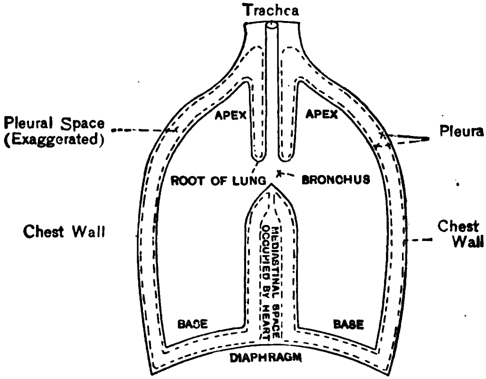


Fig. 55. Diagram of the Lungs and Pleuras.

the upper surface of the diaphragm. The lung is thus free, except at its root, where the air and blood tubes enter. A very small quantity of liquid moistens the surfaces of the pleuras on the outside of the lung and the inside of the chest wall, so they move easily one upon the other during respiration. As the lungs are always distended enough to fill the chest cavity, these two surfaces are always in contact.

Pleurisy. — Pleurisy is an inflammation of the pleura. In breathing there is pain from friction or adhesion of the pleuras of the lungs and chest wall.

Pneumonia. — Pneumonia is inflammation of the lungs. It was formerly called "lung fever." It is due to bacteria.

The Diaphragm. — The diaphragm is a thin muscle making a complete partition between the abdominal cavity and the chest cavity. It is convex above and concave below where it fits over the liver and stomach. Its front edge is attached to the inside of the chest wall about opposite the lower end of the breastbone. Its general position is shown in Figs. 53, 55, and 58.

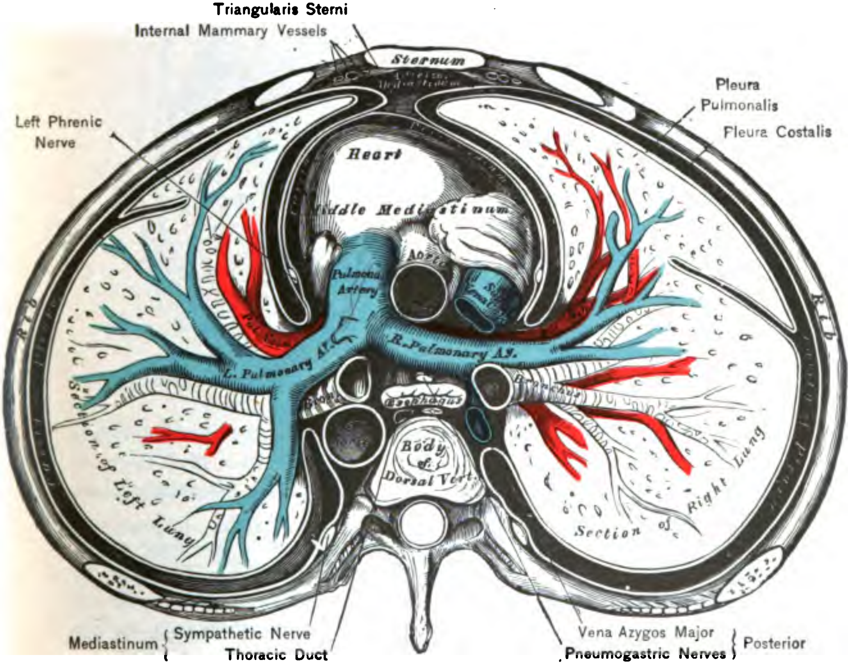


Fig. 56. A Cross-section of the Chest, showing the Heart, Lungs, and Blood Tubes.

To show the Action of the Diaphragm and Lungs. — MATERIAL. — Bell jar with stopper, sheet of rubber (such as used by dentists) large

enough to cover the mouth of the jar, toy rubber balloon, cork (rubber preferred), glass tube, cotton string, collar button.

PREPARATION. — Lay the collar button on the center of the sheet of rubber, double the rubber over it, stretching the rubber strongly over the head of the button, and tie the head firmly in its place. Stretch the sheet of rubber over the base of the jar with the base of the button on the outside, and fasten with string. Bore a hole in the cork, and fix the glass tube snugly in it, so that the lower end of the tube will extend about half-way down the jar. Tie the balloon on the lower end of the glass tube.

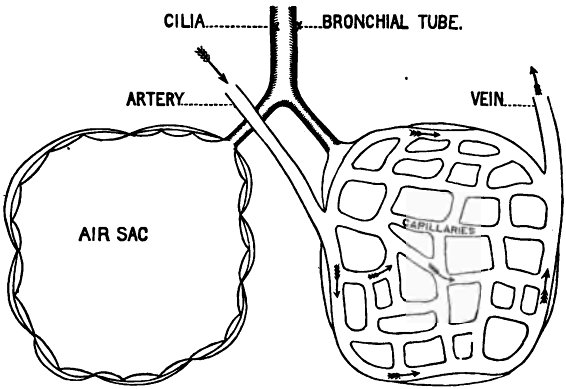


Fig. 57. Minute Structure of the Lungs, showing Air Sacs and Capillaries.

EXPERIMENT 1. — Insert the balloon and tube into the jar, inflate the balloon, and while it is inflated tightly cork the jar. If all the parts fit well, the balloon should now remain inflated, and the rubber which represents the diaphragm will be arched upward.

EXPERIMENT 2. — Pull the diaphragm down, using the base of the collar button as a handle. This shows the expansion of the lung by the pressure of the external air when more space is given by the depression of the diaphragm. On releasing the diaphragm, it springs upward, and the balloon becomes smaller, driving out part of the air that was in it. This shows how expiration is accomplished, so far as the diaphragm is concerned.

If a bell jar is not at hand, a lamp chimney or a quart bottle may be used, after cutting off the bottom, as follows: File a deep notch across

near the bottom; heat an iron rod, and apply the end of it to one end of the notch, and slowly draw the rod around to the other end of the notch (the rod may need to be reheated). After cracking off the bottom of the jar, file the edges so they will not cut the rubber.

Let each pupil make a drawing, showing the position of the parts in inspiration and in expiration.

The Movements of Respiration. — The process of respiration consists of two acts, inspiration and expiration.

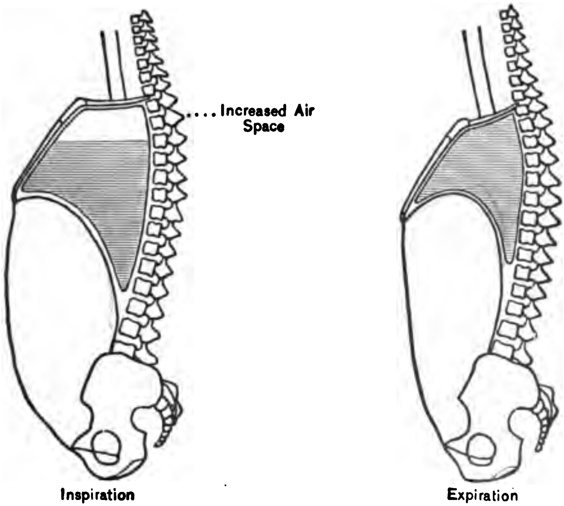


Fig. 58. Sections of the Body in Inspiration and Expiration.

Two Active Forces in Inspiration. — In inspiration the principal active forces in the body are, first, the diaphragm; and, second, the muscles which raise the ribs.

Work of the Diaphragm in Inspiration. — The diaphragm is a muscle, and when its fibers shorten, the diaphragm is pulled down. In moving down it presses on the abdominal organs, and makes the abdomen protrude forward and sideways. This lowering of the diaphragm increases the

space in the chest. Air, from the outside, enters through the trachea, presses on the inside of the elastic lungs, and makes their bases extend, following the diaphragm in its descent. The bases of the lungs remain in contact with the upper surface of the diaphragm all the time.

Work of the Chest Walls in Inspiration. — Certain muscles of the chest wall raise the ribs and breastbone. This widens the chest, and the air, as before, presses in through the open windpipe, and keeps the sides of the lungs in contact with the inner surfaces of the chest walls.

Effort required in Depressing the Diaphragm. — Inspiration requires considerable effort, because the diaphragm in its descent presses upon the elastic organs of the abdomen (stomach, liver, etc.), and these organs, in turn, are pressed against the elastic walls of the abdomen. It is somewhat like pressing a pillow down into a rubber bag; the pillow springs up as soon as the pressure is stopped, because of its own elasticity as well as that of the bag. Therefore, as soon as the diaphragm relaxes, the elastic walls of the abdomen retreat, and the abdominal organs rise to their former place.

Effort required in Raising the Ribs. — When the ribs are elevated, the cartilages which connect the front ends of the bony parts of the ribs with the breastbone (see Fig. 6) are slightly bent. When the muscles relax, the elasticity of the rib cartilages makes the ribs spring back to their former position, thus reducing the chest to its former width.

Expiration Easy. — Thus we see why expiration is easy; in fact, "does itself" (in ordinary respiration) by elastic reactions. But inspiration is harder than it would be if it

were not for the fact that the descent of the diaphragm meets resistance, and the ribs, in rising, have to overcome resistance in bending the rib cartilages, and in raising the weight of the chest walls and shoulders.

Potential Energy stored in a Door Spring. — When one opens a door that has a spring to shut it, he has to use more force to open the door than he would if he did not have to bend (twist or compress) the spring at the same time. But no effort is needed to shut the door. The door was opened and shut at the same time; *i.e.* when the door was opened, force was stored in the spring (in the form of what is called potential energy), and this stored energy shuts the door while we pass on. We can better afford to expend more energy while opening the door than to take the extra time to shut it. If, then, a door with such spring were fastened open, it might remain open for a long time. When released it flies shut. If one, in this case, asks, "Who shut the door?" the answer is, "The person who opened it."

The Storing of Energy during Inspiration. — So in the act of inspiration we perform a double work in storing energy by which the expiration is performed without active muscular effort.

Review of Forces of Respiration: —

Forces of Inspiration.

1. Depression of the diaphragm.
2. Muscles elevating the ribs.
3. Pressure of the external air.

Resistances to Inspiration.

1. Compression of the abdominal organs and stretching abdominal walls.

2. Bending the rib cartilages and lifting the chest.
3. Stretching the lungs.

Elastic Reactions of Expiration.

1. Elastic reaction of the abdominal walls and contents.
2. Elastic reaction of the rib cartilages.
3. Elastic reaction of the lungs.

Forced Respiration. — Thus far we have been speaking of ordinary respiration. In forced respiration, as in shouting, many muscles are brought into play to expel the air rapidly and forcibly. In such an act as coughing there is vigorous action of the abdominal muscles.

Abdominal and Thoracic Respiration. — The main part of respiration is performed by the diaphragm, and is therefore called diaphragmatic or abdominal breathing. Breathing by means of the chest walls is called thoracic, or costal breathing.

The Rate of Respiration. — Adults breathe about seventeen or eighteen times a minute, or about one breath to four heart beats. The rate is increased by exercise, temperature, digestion, excitement, age, etc.

Special Forms of Breathing. — Coughing is a forcible expiration, usually directed through the mouth, and for the purpose of getting rid of some irritating substance. In sneezing there is first a deep inspiration, and then the air is forced out, chiefly through the nose. Sneezing may be prevented by pressing firmly on the upper lip. Hiccuping is sudden inspiration, produced by a jerky action of the diaphragm, accompanied by a sudden closing of the entrance to the windpipe. In case of choking it is well to hold the head well forward, and perhaps downward. A smart slap between the shoulders sometimes helps dislodge

anything stuck in the throat, and it may be necessary to hold a child with the head downward. There are various

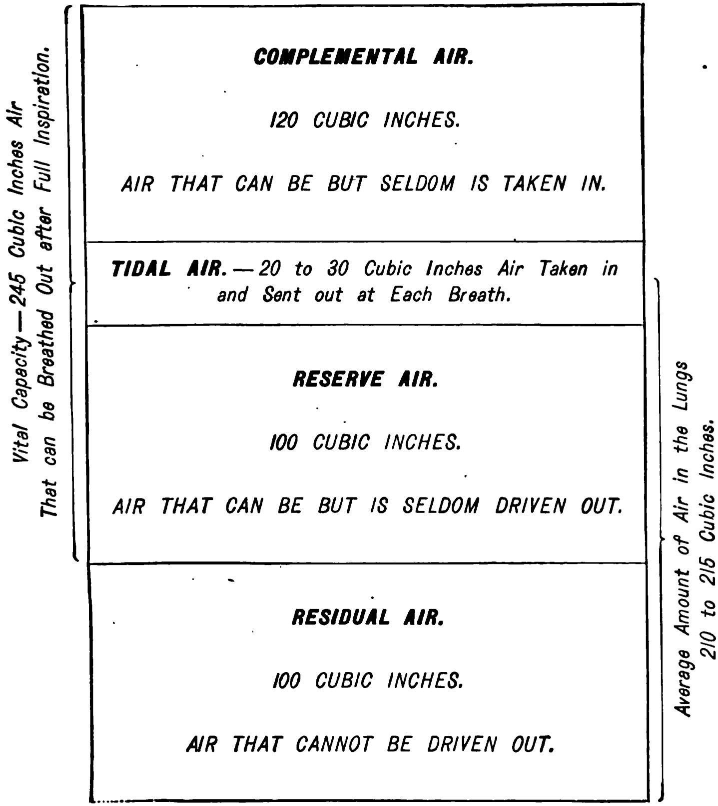


Fig. 59. Diagram of Lung Capacity.

other peculiar forms of respiration, such as yawning, sniffing, laughing, etc., which you can explain after watching and thinking about them.

Capacity of the Lungs. — Have the class stand, and each pupil raise his right hand.

1. **Tidal Air.** — Let all breathe together, at the ordinary rate and depth, and let the hand rise about three inches during inspiration, and fall again during expiration. The amount of air taken in at an ordinary breath is from 20 to 30 cubic inches, or about a pint. This is called tidal air.

2. **Complemental Air.** — As before, let the hand go up and down with the breathing, but at the end of the third inspiration, instead of stopping with the usual amount, keep on breathing in as much as possible, letting the hand rise accordingly. This air that can be taken in above the ordinary breath is called the complemental air, and it is estimated to be, on the average, about 120 cubic inches.

3. **Reserve Air.** — Begin as before, and at what would be the end of the third expiration continue to drive out as much air as possible, indicating the degree by lowering the hand. This air that can be breathed out beyond the ordinary expiration is called the reserve air, and is reckoned at about 100 cubic inches.

4. **Residual Air.** — The air cannot all be breathed out. The remainder is called the residual air, and is computed to be about 100 cubic inches.

The Vital Capacity. — All the air that can be breathed out after a full inspiration, *i.e.* the sum of the complemental, tidal, and reserve air, would be about 240 to 250 cubic inches, and is called the vital capacity. Of course these figures represent only the average of certain experiments and observations. By practice any one can considerably increase his vital capacity.

A Test of the Capacity of the Lungs. — A simple method of measuring these stages of respiration is to take a gallon bottle and first carefully graduate it to pints by pouring in water and marking on the outside with a file. Then fill the bottle with water, invert it in a trough of water, and exhale into it by means of a rubber tube.

Hygiene of Breathing. — Those persons who take constant exercise in the open air are not likely to suffer much from deficient respiration. But persons who lead an indoor

life, especially those who are sitting much of the time, need to pay especial attention to the matter.

The Nasal Passages. — The nasal passages are fitted for the introduction of the air (1) by being narrow, but of large area; (2) by having their lining membranes richly supplied with blood; (3) by the abundant secretion of mucus by this membrane. The air, coming through this narrow channel, is warmed, and a large part of any dust it may contain is caught by the sticky mucus that covers all the walls of this passage-way.

Adenoids. — When any person breathes through the mouth, there is something wrong somewhere in the nasal passages. Children who breathe through the mouth and "snore" at night generally have a growth of gland-like tissue called "adenoids" at the back part of the nose and behind the palate. Not only is breathing through the mouth bad because it allows cold air and dust to go down into the windpipe, but the mouth breather cannot get enough air properly to aerate his blood. Mouth-breathing children, therefore, are frequently peevish and not disposed to play. They do not sleep or eat well, are apt to be croupy, and are more liable than nose-breathing children to contract diseases like diphtheria and croup. Such children should be taken to the doctor and the adenoids should be removed.

Deep Breathing. — It is a grateful relief to the whole system to stand, stretch, inhale deeply and slowly several times, and to repeat this every hour or so. Every one engaged in office work or studying should form this habit, especially if he does not give an hour daily to exercise.

Control of Respiration. — Breathing is an involuntary action. It is under the control of the nervous system, and,

without attention on our part, it goes on, varying in rate according to the needs of the bcdy. About every fifth breath is a little deeper than the others, and if we are sitting in a cramped position, or are depressed, this occasional deeper breath is still more marked and is called a sigh. If the tissues are not well supplied with oxygen, they make it known to nerve centers through the nerves, and, by reflex action, breathing is quickened.

Summary. — 1. In the lungs the air and blood are brought very close together, only the wall of the capillary and that of the air vesicle being between them.

2. Through these two layers oxygen passes from the air sac into the blood. Carbon dioxid, water vapor, and other wastes pass from the blood into the air sac.

3. The mucous membrane of the air passages secretes mucus which is driven toward the nostrils by the ciliums.

4. The chest is lengthened by the lowering of the diaphragm, and widened by the lifting of the ribs, giving greater space, which is filled by external air expanding the lungs.

5. Inspiration requires extra effort; but ordinary expiration is without effort because of the elastic reactions.

6. Forced expiration, as coughing, requires active muscular effort.

7. The vital capacity may be increased by practice and by exercise.

8. We should breathe through the nose, not through the mouth.

9. Respiration is under the control of the nervous system.

Questions. — 1. Is it well to see how long one can hold his breath?

2. Should the head be covered by bedclothes?

3. How is respiration affected by a stooping posture?

4. What are the "lights" of an animal?

5. Of what advantage is it that the cartilages of the windpipe are C-shaped, and not complete rings?

6. From the statements in this chapter of the amount of air taken in at each breath and of the rate of breathing, find out how much air is breathed in an hour. How much in twenty-four hours?

CHAPTER X.

INTERNAL RESPIRATION.

Composition of the Air. — Air has about 20 per cent oxygen and 80 per cent nitrogen, or one fifth oxygen and four fifths nitrogen. There is a very small amount of carbon dioxid, and usually there are traces of other gases.

Experiments illustrating Internal Respiration. — MATERIAL NECESSARY. — A piece of candle an inch or two long, two tumblers, a tube eight inches long (a straw will serve), a nail, and lime water. The lime water should be prepared the day before by putting a piece of fresh quicklime as big as a hen's egg in a quart of water. The next morning carefully pour off the clear water for use in experiment.

EXPERIMENT 1. — Light the candle and hold a cold tumbler inverted a little above it. The moisture that dims the inside of the tumbler is water that has been produced by the burning of the candle. The oxygen of the air unites with something in the candle and forms water.

EXPERIMENT 2. — Breathe into a cold tumbler. The tumbler is dimmed by the water in the air we breathe out.

EXPERIMENT 3. — Lower a tumbler over the burning candle till the tumbler rests on the table. Observe that the flame is soon put out. Carefully lift the tumbler and slip one hand under it so that the palm tightly covers the mouth of the tumbler. Invert the tumbler. Lift one edge of the hand and pour in about two tablespoonfuls of lime water. Thoroughly shake the tumbler, keeping it tightly closed. The lime water is turned milky by the carbon dioxid produced by the burning candle. There is carbon in the material of the candle, and the union of oxygen with this carbon produces carbon dioxid.

EXPERIMENT 4. — Pour about two tablespoonfuls of lime water into a tumbler and breathe through it by means of a tube. The lime water is turned milky by the carbon dioxid in the breath. There is carbon in

the tissues of the body. Oxygen unites with this carbon, forming carbon dioxid. We know that there is carbon in beef, for when it is overbaked we see the black carbon where it is charred. There is carbon in our muscles and in all the other tissues.

EXPERIMENT 5.— Place a nail, or any piece of iron, in a tumbler of water. It will soon rust. Rusting is caused by the union of oxygen with the iron. When anything unites with oxygen it is said to oxidize. When the union is rapid, as with the burning candle, it is called combustion.

EXPERIMENT 6.— Hold a thermometer at arm's length. It shows the temperature of the air,— of the air you are breathing in. Breathe for a few minutes upon the bulb of the thermometer and you have proof that the air we breathe out is warmer than the air we breathe in.

How the Body is like a Candle.—The burning candle and the body both produce heat. To do this each must have oxygen. The oxygen unites with carbon and other elements in each, and produces carbon dioxid, water, and other substances. And just as a candle flame is soon put out in a closed tumbler, so life would be destroyed by suffocation if an animal were shut in an air-tight room.

Exchanges between the Air and the Blood in the Lungs.— Whatever the air coming from the lungs contains that was not in the air entering them it has taken from the blood, and what the air has lost it has given to the blood. The air in the air vesicle is separated from the blood in the pulmonary capillaries only by the thin wall of the air vesicle and the thin capillary wall.

What the Air gets from the Blood.—Carbon dioxid, water, and other waste matters pass from the blood through this thin partition into the air vesicle, to be sent out by later expiration through the bronchial tubes and windpipe. The air also gets heat from the blood (see Fig. 60).

What the Blood gets from the Air. — Oxygen from the air in the vesicle passes through these layers into the plasma, and most of it is quickly picked up by the colored corpuscles. The colored corpuscles are the carriers of oxygen.

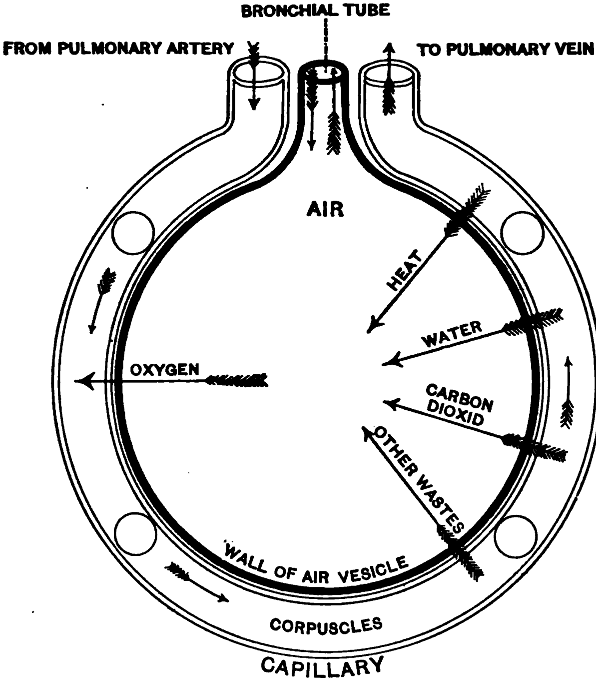


Fig. 60. Exchanges between the Air and the Blood in the Lungs.

Hemoglobin and Oxy-hemoglobin. — The hemoglobin in the colored corpuscles is eager to unite with oxygen. Hemoglobin is of a dark color, and gives the dark color to the blood which enters the lungs. When oxygen unites with the hemoglobin it forms oxy-hemoglobin, which is of a bright red color. Hence the change in the color of the blood

in the lungs from a dark bluish red to a bright scarlet. This bright blood is usually called "arterial," and the dark "venous"; but it must be remembered that the blood in the pulmonary artery is dark, and in the pulmonary veins bright.

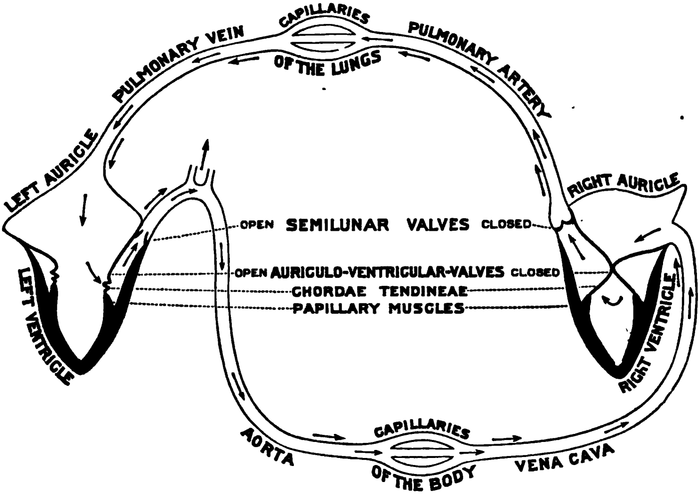


Fig. 61. Circulation in the Capillaries of the Lungs and in the Capillaries of the Body.

The Changes in the Blood. — What does the blood do with the oxygen that it gets in the lungs, and where did it get the carbon dioxid and other impurities that it brings to the lungs? Let us follow the blood and see. From the pulmonary veins the blood goes to the left heart, and is pumped to all the tissues except the lungs. Let us follow a branch of the aorta that leads to a muscle.

The Production of Heat and Motion in the Body. — When a muscle works it becomes warmer. The rise in temperature has been repeatedly proved by experiment. We know that the blood is flowing more rapidly through the muscle

when it is at work. The more rapid stream brings the muscle more oxygen. This it needs, for it is by the oxidation of the muscle (or substance in it) that the muscle produces heat and motion. The oxidation in our tissues is a slow oxidation, more like the rusting of iron than the burning of a candle. Oxidation in our bodies never produces a high degree of heat and never produces light.

Increased Blood Flow is the Result of Exercise. — When we exercise, the muscles need more oxygen. They also need to have removed the waste matters that they are so rapidly producing at this time. How is the oxygen brought and the waste removed? By the blood, you answer. True; but what makes the blood come and go faster at this time? By reflex action, you reply. The muscles send a message to a nerve center, and this nerve center sends back a message to the blood tubes, making them widen, and the heart also may be made to beat faster.

Increased Respiration from Exercise. — But would it do any good to have the blood flow through the muscles faster, if it could not bring more oxygen, and take away and get rid of more wastes? You will say no. To give the extra oxygen and take out the carbon dioxid, the lungs cannot, of themselves, take in and send out air. The work of pumping air depends on the muscles of respiration, the diaphragm, and the muscles that elevate the ribs. These muscles will not work faster unless they are ordered to do so. A message must be sent to them telling of the need. Thus, by a series of reflex actions, all these processes are kept in close relation to each other. It must be borne in mind that increased blood flow is the result, and not the cause, of the increased activity of the tissues.

Temperature of the Body. — Insert the bulb of a thermometer into the mouth, and keep it there three or four minutes to find the tempera

ture of the inside of the body. For this it is better to use a clinical thermometer, if one can be obtained. The average temperature of the tissues within the body is about 98.5° F.

How the Body is like a Stove. — The body may be compared to a stove. Into one we put fuel and produce heat. In the other we get heat from food. Both take in oxygen. Both produce carbon dioxid, water, and other waste matter.

How the Body differs from a Stove. — But the body is not like the stove in burning the fuel (food) *directly*. The food is first made into tissues, or material stored in the tissues. It is as though we were to build a stove entirely of coal, and then start a fire in it. In that case it would produce heat not merely by burning in one place within, but would be burning throughout the whole of its substance. This is the case with the body.

Oxidation in Tissue the Source of Heat in the Body. — The muscles make up nearly half of the weight of the body. They are more active than most of the tissues. We would naturally infer, as is the fact, that they are the chief source of the heat produced in our bodies. The tissues of the body are oxidizing all the time. But when in vigorous action they oxidize very much more rapidly.

Production of Heat in the Liver. — Next to the muscles, in importance as a heat producer, is the liver, which is the largest gland in the body, and, as we shall soon see, one of the most active. The blood, as it leaves the liver by the hepatic vein, is hotter than anywhere else in the body.

How the Body is like a Locomotive. — But it will be better to compare the body to a locomotive, as we produce not only heat, but motion: — 1. Both are warm; 2. Both move; 3. Both use fuel (food or coal); 4. Both take in

air. 5. Both give off gases, consisting mainly of carbon dioxid and water vapor.

How the Body differs from a Locomotive: — 1. The body does not get hot enough to burn; *i.e.* the oxidation is relatively slow, and is not *combustion*. 2. The oxidation of the body never produces light. 3. The oxidation in the body is always in the presence of moisture.

The Amount of Carbon Dioxid given off. — When the breath is held for some time, the carbon dioxid in the expired air may reach 7 or 8 per cent. During violent exercise the amount of carbon dioxid given off may be more than twice as much as when we are at rest. In ordinary respiration there is one hundred times as much carbon dioxid in the air we breathe out as there was when it was taken in. Oxygen is carried chiefly in the corpuscles, but the carbon dioxid is carried in both plasma and corpuscles.

Effect of Re-breathing Air. — Every one knows how unpleasant it is to breathe the air of a close room where many people are present. In many persons such air causes headache and drowsiness. This effect is not due to the reduced amount of oxygen, nor is it due to the increase of carbon dioxid. It is believed to be due to the "organic impurities" which are thrown out in the expired breath. It is this matter that gives the offensive odor to a room which is kept close and warm after a crowd has been in it. If in a crowded lecture room you divide the space by the number of people present, you find that each one has really very little room. In such rooms special attention to ventilation is necessary, or great injury will be done. When we learn how many cases of lung

diseases are found wherever people are crowded into ill-ventilated rooms, we can realize the force of the statement, "Man's own breath is his worst enemy."

Summary of Respiration. — The tissues need oxygen; air is sucked ~~pumped~~ into the lungs; this air gives oxygen to the blood; the blood carries it to the tissues.

In oxidizing, the tissues produce energy (heat and motion) and give off waste matter (water, carbon dioxid, etc.); these the blood carries to the lungs, the lungs give them to the air, and the air carries them out of the body.

The pumping of the air in and out and the exchanges between the air and the blood in the lungs may be called "external, or mechanical respiration." The action of the oxygen of the blood in the tissues is the "real, or internal respiration."

Summary. — 1. In passing through the lungs air loses oxygen, and gains water, carbon dioxid, and other wastes.

2. Oxygen is carried chiefly by the colored corpuscles of the blood; it unites with hemoglobin in the corpuscles, forming **oxyhemoglobin**, and gives the blood its bright scarlet color.

3. The energy of heat and motion in the body results from the oxidations in the tissues.

4. Air once breathed is unwholesome. The air of living and sleeping rooms needs constant renewal.

5. When we exercise more, the muscles need more oxygen, so the heart must beat faster and we must breathe faster.

6. The body is like a locomotive in producing heat and motion by oxidation.

7. Air, once breathed, has one hundred times as much carbon dioxid as before.

Questions. — 1. In what part of the lungs is the best air? Where the worst?

2. Is it easy to determine by the color of blood flowing from a wound whether it is arterial or venous? Why?

3. How is the air of a room affected by having many lamps or gas jets burning?

4. How is air affected by gasolene or kerosene stoves?

5. Could a locomotive be run by feeding it with bread and meat?

CHAPTER XI.

all

VENTILATION AND HEATING.

Need of Proper Ventilation. — When one is actively exercising he may keep warm outdoors even on a cold winter day. For the heat of the body depends on its internal fires, the oxidation of its tissues. But if we are inactive, these fires burn feebly, and we need outside heat. While air is free, it really costs a good deal of money to have it properly warmed.

A Lack of Effective Systems of Ventilation. — Lung diseases are rare in the regions where the windows and doors may be kept open most of the days of the year. It is from shutting ourselves in so closely that we suffer. This is especially true where many people are housed in a comparatively small space, as in many public buildings. But in our private dwellings, even when the owners are amply able to secure the best appliances, defective apparatus is often put in. *Any system that does not provide for a constant renewal of the air is defective.*

The General Principles of Ventilation. — Of the forces that renew the air of rooms two are natural, (1) diffusion and (2) the wind; and two are artificial, (3) warm air shafts and (4) fan systems.

Diffusion. — Gases tend to mix. We know that if a bottle containing an odorous substance is opened in a room where there are no air currents the odor tends to

spread equally through the room. If a person is in one corner of a large room, where there are no inlets or outlets, and no currents, as he uses the oxygen immediately around him, the oxygen farther away will diffuse toward him so that he will continue to get oxygen as long as there is any in the room. So, too, the gases that he breathes out will not remain confined to the space directly about him, but will spread nearly evenly throughout the room. The same takes place in the open air, without wind. So, then, if the windows and doors are open, the air of the room will be renewed by diffusion.

Wind. — Motion of the air renews faster than mere diffusion. Strong wind forces its way through the cracks around windows, and when windows are open on opposite sides of a room there is usually enough breeze to renew the air. But during part of the year this cannot be done.

Artificial Renewal of the Air. — The renewal of the air in most cases depends on the fact that heated air rises. Heat expands air. It is then lighter, bulk for bulk, than cooler air. The heavier surrounding air presses the lighter air upward. If there are outlets above and below, the heavier, colder air will press in below, and push the lighter, warmer air out above.

Grates as Heaters. — Grates are the simplest and probably the earliest form of heater. The fire throws out heat in straight lines, or as we say, *radiates* heat into the room. So much of the heat goes directly up the chimney that a grate is very wasteful of fuel.

Grates as Ventilators. — But a grate is an excellent ventilator. There is always a decided draft toward a grate fire. This means a constant renewal of air. The air

pushing toward the grate may be cold, and this has disadvantages that are hard to overcome in cold weather if there is no other way of supplying heat. But it is a serious question whether, with all our modern improvements in heating, we have better air in our houses, or take cold less often than our grandfathers, even if they did "roast on one side while they froze on the other."

Stoves as Heaters. — A stove is a very much more effective heater than a grate. In the first place the stove gives off heat on all sides. In the second place a good deal of heat is given off by the stovepipe; while in the grate almost no heat is saved from the flame and smoke. Again, the fire can be better regulated in the stove.

Air Currents produced by Stoves. — There is always a current of heated air rising above a hot stove. Children make whirligigs and other toys to place in these up-currents. When this heated air reaches the ceiling it passes along the ceiling, and comes down along the walls in the colder parts of the room. At the same time colder air is flowing along the floor toward the stove. This, in turn, is heated and rises, making a constant circuit, along the floor to the stove, up from the stove to the ceiling, along the ceiling to the walls, and down the walls to its starting-point, again to repeat the round.

Stoves as Ventilators. — If there is an opening at the top of the room, heated air will escape through it. Often the heat is used to warm upstairs rooms in this way. If a window is open at the top, some heat is lost. To make up for the losses above named, and also for the air that enters the stove and goes up the chimney, more air is drawn in usually around doors and windows. It is especially noticeable where there are openings near the floor.

For the cold air is heavier than the warm air and continually pushes the warm air up and out of the room wherever it can. But the stove does not send as much air up the chimney as the grate does, and so does not draw in as much fresh air. It is therefore not a good ventilator. But the stove gets much more heat from a given amount of fuel.

A Stove and Jacket.—In some cases a jacket is placed around a stove, and a duct from the outer air connects

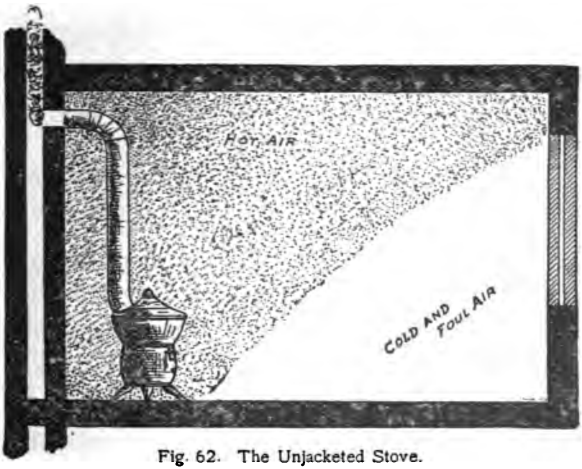


Fig. 62. The Unjacketed Stove.

with the lower part of the space inside of the jacket and outside of the stove. Then as the air heated by the stove rises, fresh air is drawn in from outside to be warmed. In this case the direct heat from the stove is shut off from the room. Heat radiates in straight lines. When one holds out his hands beside a stove, the heat he receives is radiant heat. Most of the heat from a grate is radiant heat. But in a jacketed stove the heating by air currents is called heating by convection.

The Furnace. — A furnace is practically a jacket stove placed in a basement. Hot-air furnaces have this good feature, that they are all the time sending fresh air into a room. The main trouble is, the air is usually too dry. There should be in the furnace a pan of water to furnish moisture to the air.

Foul-air Shafts and Fans. — Although in private dwellings heated by furnaces there is no special provision for the escape of foul air, there is ordinarily sufficient renewal of the air. But in public buildings there should be escape flues for foul air. Frequently a large foul-air shaft is built near the center of the building, and a small stove placed in it to create a sufficient up-current. In many public buildings the currents created by heat are not strong enough to renew the air properly. Revolving fans are used, which force the air, properly heated, into the room.

Direct Heating. — In heating by steam or hot water, if the radiators are placed in the room they give direct or radiant heat. This system is called direct heating. It gives direct heat, and produces air currents within the room. In itself it has no provision for renewing the air.

Indirect Heating. — In indirect heating, coils of steam or hot-water pipes are placed in air shafts which lead up to the rooms above, and also have ducts to the outside. As the air is heated by the heat of the pipes it rises into the rooms above, and fresh, cold air presses in through the ducts, to be, in turn, heated and sent up. If there is at the same time a proper escape for the foul air, this makes an excellent system.

A Combination of Direct and Indirect Heating. — It is a good plan to combine direct and indirect heating. Where

there is a grate in a room, it serves very well as a foul-air shaft, especially when there is a fire in the grate. It is well to have the flue from the grate in the same chimney with that from the smoke-pipe from the furnace, as then the heat from the smoke will cause a constant up-draft in the grate flue, whether there is a fire going in the grate or not.

With a grate, in private houses, there is ordinarily no need of other foul-air shaft for any room. But it is very desirable to have at least some "indirect" heat, so that the fresh air introduced will be sufficiently heated.

If the introduction of air is thus provided for, it is then safe to put on double windows and make the cracks around the door very tight. Without any special provision for the renewal of the air these cracks are the means of safety. In houses heated by furnaces, steam, or hot water, the floor is likely to be warmer from the escape of heat from the heater itself, and from pipes or air ducts under the floor.

Double Windows. — There is a very common misunderstanding as to the cold felt near a window in cold weather. It seems that air is entering; but a little reflection will show that even if the window were air-tight this effect would be produced, for the air near the window is cooled by losing heat to the outer air through the glass. The air next to the window, thus cooled, is heavier, and falls to the floor; and if there is any source of heat in the room, this cold air will pass along the floor to that source of heat, up from the heating body to the ceiling, and across the ceiling, and so on around again. There may thus be currents without any change in the quality of the air. It is economy to use double windows and prevent the loss of heat through the glass. So both economy and comfort suggest to us that we reduce as much as possible cracks around doors and windows, use double windows, make

vestibules at entrances, and build special ducts by which fresh air may enter, and heat it properly on its way in.

To Air a Room without Draft. — To introduce fresh air into a room without having a draft, a good plan is to get a board four inches wide and as long as the width of the window sash. Raise the window, place the board under it and shut the window down upon the board. This will allow air to enter between the upper and lower sash, and it will be directed toward the ceiling. This is of double advantage; in the first place, it does not strike any one directly; in the second place, it mingles with the warm air of the upper part of the room before it reaches us.

Wearing Slippers. — In rooms heated by stoves or grates there is always more or less cold air moving along the floor. Wearing slippers in such a room causes many persons to take cold. The ankles have been warmly dressed through the day and while the person was more active. Especially if one is studying there is a tendency to draw the blood away from the feet and make them cold. It is restful, in the evening, to take off the shoes that have been worn during the day; but, for most persons, it would be better to put on a pair of loose shoes so the ankles will be protected. The floor is usually the coolest place in a room. In sitting in a room heated by a grate, or stove, the head usually gets the most heat, and the feet the most cold, just the reverse of what it should be. If much heat escapes from a furnace, the floor may be warm. Those who use stove heat in loosely built houses, learn to keep the feet up on a stool when sitting in a room in cold weather.

Ventilation of Cellars. — The cellar is the source of contamination of the air of many houses. Of course a cellar

ought to be dry, well lighted, and well ventilated. But since many of them are dark and ill ventilated, especial care should be taken to keep them dry. Fruit and vegetables should not be allowed to decay in the cellar. On entering many houses one can at once detect the smell of decaying potatoes and other vegetables. Such material should be promptly removed. The best time to ventilate a cellar is at night, for if the cellar windows are opened in the day time, the entering air will deposit moisture, making the cellar more damp instead of dryer.

Summary. — 1. Lung diseases usually accompany close confinement, but are rare with those living in the open air.

2. Air in rooms needs constant renewal.

3. Grates are good ventilators, but not economical heaters.

4. Stoves are economical heaters, but poor ventilators. Both grates and stoves heat very unevenly.

5. All crowded rooms, as schoolrooms and churches, need special inlets for fresh air and outlets for foul air.

6. The most common means of withdrawing the air is by foul-air shafts. Heat is the force relied on, but the removal of foul air is usually inadequate, on account of the slowness of the current or the narrowness of the outlet, or both combined.

7. Fans are much more certain to be effectual.

8. Steam and hot water may heat directly (by radiation) or indirectly (placed in flues). It is best to combine direct and indirect heating.

Questions. — 1. How can we renew the air of a room without having unpleasant drafts?

2. Should bedroom windows be open at night? Is night air bad?

3. What dangers in the use of hard coal?

4. Should there be a damper in the smoke-pipe of a hard coal stove?

5. What do miners mean by "choke damp"?

6. Compare stove and furnace heating.

7. Compare heating by steam and by hot water.

8. Read about the "Black Hole of Calcutta."

CHAPTER XII.

a.cl.

DUST AND BACTERIA.

The Air is washed by Rain or Snow. — Every one will recall how delightfully refreshing the air is after a rain or a snowstorm. This is not due merely to the fact that the air is cool. It is clean because it has been washed. The rain and snow absorb most of the various impure gases that are in the air. The raindrops and snowflakes also bring down with them many particles of dust that were floating in the air. Take some of the snow that has fallen in a town. It looks pure in its almost dazzling whiteness. But melt some of it, and you will usually find that the water has an inky tinge, showing that as the flakes sifted down through the air they caught myriads of particles of dust.

The Sources of Dust. — Where soft coal is used to any large extent it is one abundant source of this dust. In summer dust has many sources. The dust that blows into your face, and perhaps into your mouth, may be made of dry soil. Take a dry clod and drop it; it falls quickly to the ground. Crush it in your hand before dropping it, and much of it floats in the air for some time. Any substance that is easily dried and reduced to powder may form part of the common dust. The dust that you wipe from your eye, or is caught by the mucus of the nasal passages, may, instead of being made of clean soil, be from the excreta of horses, decayed leaves, wood, grass, etc. Indoors we are

constantly making dust by wearing out our clothes. Many of the tiny particles that we see floating in the sunbeams are bits of cotton or woolen fibers. Shake any garment in a beam of light to see how much dust is given off. The worn-off particles of our shoes, books, floors, all contribute to the ever-present dust.

The Effect of Dust on the Lungs. — This dust is irritating to the lungs and respiratory passages. There is provision, as we have seen, for catching and getting rid of a good deal of it. But still much is taken into the lungs. Examination shows that the lungs have many black specks from particles of carbon, etc., that have become lodged, and are of no benefit, to say the least.

Composition of Live Dust. — Bad as this dead dust is, the injury from it is slight compared to that from live dust. We know that certain seeds float in the air, carried along by the wind. But these are comparatively heavy, and soon sink to the ground.

We all know pollen. At certain seasons it forms, in the vicinity of cornfields, for instance, a considerable part of the dust. This is alive. It will grow if it falls on the stigma of the right plant at the right time. Such dust will not grow in our bodies. We do not furnish a soil in which it can grow. It merely adds to the amount of irritating dust.

Puffballs and Molds. — We have seen puffballs give off a cloud of dust when they are crushed. So, too, from a patch of mold, when brushed, we often see a little cloud of dust. This dust is composed of live spores that will grow in suitable places and conditions.

Yeast. — If we set a tumbler of cider on a table in a warm room, in a few days it ferments. This is due to

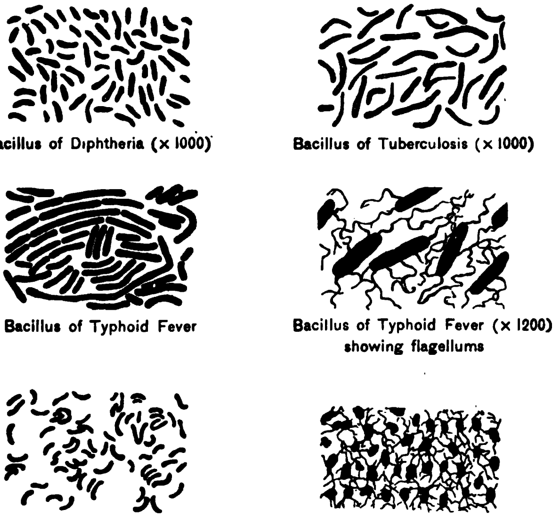
a kind of living germ or spore that has gotten into it from the dust on the fruit before it was crushed, or from dust in the room. Boil the cider to kill the spores already in it, and cork it securely so that air cannot get at it, and it will not ferment. These are a few instances of kinds of living dust that do not affect human beings any more than so much dead matter.

Disease Germs. — But there are floating in the air many kinds of spores that may grow in our bodies. We know that many of our contagious diseases are due to the growth of some of these spores in our bodies. Our bodies are a good soil for certain germs. The germs that cause consumption, typhoid fever, Asiatic cholera, erysipelas, diphtheria, lockjaw, the grippe, malaria, yellow fever, and blood poisoning are well known. Microscopists know them when they see them as readily as we know peas from beans. And it is proved beyond all doubt that these germs get into our bodies by being breathed in, or by being eaten in food, or in drinking water, or by introduction into the blood in wounds. We have reason to believe that smallpox, measles, mumps, whooping-cough, and scarlatina are caused by germs, but these diseases have not been studied so successfully.

How to avoid Germs. — How can we avoid or get rid of dusts of these kinds? To exterminate any plant, we try to keep the seeds from ripening, and to kill all that do ripen. Let us take a case that, while not pleasant to think about, is too terribly true to allow of being called an imagined case.

The Danger from Consumption. — A consumptive spits on the pavement. In this sputum are probably hundreds, if not thousands, of germs known as bacilli (*Bacillus tuber-*

culosis). They are alive. Now, so long as they remain on the pavement they do no harm. The sputum dries. But the bacilli are not killed by drying. With other dry material from the pavement they form part of the common dust. Any one of us may breathe some of this kind of matter any day, for there are persons afflicted with this dreaded



Bacillus of Diphtheria (× 1000) — Bacillus of Tuberculosis (× 1000)

Bacillus of Typhoid Fever — Bacillus of Typhoid Fever (× 1200) showing flagellums

Bacillus (Spirillum) of Asiatic Cholera — Bacillus of Hog Cholera (× 1000)

Fig. 63. Different Kinds of Bacilli.

disease in every community. Our bodies furnish the very best soil for the germs. We do not need to go into the street to be exposed. These germs may be brought into the most cleanly houses upon one's clothing, or by the wind.

How to avoid the Danger. — Of course, all such material known to be dangerous should be destroyed. If those suffering from such diseases were careful to burn all such matter, in time we might stamp out the diseases. But so

long as people spit upon the floors and pavements it will be difficult to prevent the spread of such germ diseases.

In hospitals such matters are now looked after with the greatest care, and in private houses where there is intelligence on these subjects. Many of the railroad and street car companies now forbid spitting on the floors of cars and stations, not merely because it is uncleanly, but because it is a means of spreading infectious diseases.

Bacteria. — These disease germs are the smallest and simplest of living things. They are plants; and while all of them that are well known have their scientific names, just as the larger plants have, they are all included in one general group called *Bacteria*.

How to avoid Dust. — We need to learn a good deal more about avoiding and destroying dust, and the things that make it. Towns and cities need more sprinkling to keep the dust down. Much more of the refuse and street sweepings and cleanings ought to be burned. The dust of a house should always be burned, as we know not what germs of disease may be in it. If we burn it, we shall surely not have to sweep up that dust again. If we send it out of doors it may come back, and we may have to handle it again and again.

Sweeping and Dusting. — So far as possible let us avoid things that make dust. When we sweep a carpet, a considerable share of the dust comes from the carpet itself, especially if the carpet is old. Curtains and tapestries of nearly all sorts not only hold dust, but contribute a good deal to it. Those who write on such subjects recommend hard wood floors with rugs instead of carpets. The rugs can be taken out of doors and shaken, and the floors wiped with a moist cloth, so that little dust is left floating in the

air of the room. Compare this with the condition after the ordinary sweeping of a carpeted room with the common broom. The dust fills the air, only to settle back on the floor and furniture. Then comes the so-called dusting. But do we get rid of the dust? For those who cannot have hard wood floors a most excellent substitute is oilcloth or linoleum.

Sweeping the Sick Room. — The improved carpet sweepers are not only convenient, but sanitary. Many a well-meaning person will sweep a carpet in a sick room with an ordinary broom when the patient is suffering from lung disease, thoughtless of the fact that a little dust on the floor is of much less significance than dust in the air we breathe. No one likes dust on the floor, but better a thousand times there than in our lungs.

Lung Diseases. — Statistics seem to show that one seventh of the deaths among the civilized races is due to lung diseases. The best authorities are now agreed that consumption is not hereditary. But it appears that there may be inherited a tendency to this disease, so that, if exposed, such persons are more likely to contract the disease than others. Probably anything that lowers the general vitality makes the system more ready to yield to any of these contagious diseases. We have all noticed what a difference there is among individuals in the readiness with which they "catch" contagious diseases.

How to ward off Contagious Diseases. — A good general condition of the body helps greatly to ward off diseases of this nature. A cheerful condition of mind and body should be cultivated. In times of widespread contagious disease, if one is terrified into the belief that he is going to have the disease, he is more likely to take it. Thorough clean-

liness, plenty of direct sunshine, care in diet, and the keeping of the body in good tone, reduce the chances of "taking" contagious diseases. An open-air life, abundant nutritious food, and freedom from anxiety are probably the best cures for the first stages of consumption.

Destruction of Germs by Colorless Corpuscles. — The colorless blood corpuscles may take these germs of disease into their substance, and destroy or change them so that the disease is warded off. In other words, they may be compared to a cat that catches and eats the mice which invade a house.

Germs killed by Plasma. — Sometimes the blood contains a substance that kills or prevents the action of disease germs. Such a substance is called *anti-toxin*, which means a counteracting poison. But the blood of most persons does not naturally contain anti-toxin, and so, if the disease germs gain entrance, the disease follows.

Danger of getting Germs into Wounds. — There is danger of introducing germs of disease in so simple an act as picking out a sliver with a pin. If such germs happen to be on the point of the pin, the mischief is easily done. Great care should be taken in any such operation to use a thoroughly clean needle or lancet. Formerly any surgical operation that required opening the body cavity, either the chest or the abdomen, usually resulted in death. Nowadays such operations are commonly successful, because surgeons sterilize their instruments, hands, and everything used about the work. They kill any germs that might be introduced. In a word, they have learned to be clean.

In caring for a patient ill of any germ disease, one should wash the hands in some disinfectant, such as chlorid of

lime, and should not touch the fingers to the lips; ignorance of these simple rules has caused many deaths.

Malaria and Yellow Fever. — Malaria is due to an *animal germ* (not a bacterium) that gets into the blood. It is introduced by mosquitoes that have bitten persons whose blood contains these germs. The same is true of yellow fever.

The Bacteria of Putrefaction. — Besides the disease-producing bacteria, there are others that cause decay and putrefaction of various kinds. They cause foods to "spoil," milk to turn sour, butter to become rancid, etc.

While these bacteria do not cause disease in the human body, they often make food poisonous. The cases frequently reported of poisoning from eating ice cream, cheese, sausage, etc., are in many cases due to bacteria in them. We should, in the first place, be careful to get good, fresh material. In the second place, it should be so kept as to prevent the introduction and development of bacteria in it. Bacteria need heat and moisture for their growth just as higher plants do.

The Preservation of Foods. — So our principal modes of keeping foods from spoiling are to keep them in a cold place, or to dry them. Or we heat them, and shut them away from the air, as in our various modes of canning and preserving foods. Salting and smoking meats, etc., preserve them by preventing the growth of bacteria. Cold does not usually kill bacteria. So milk that has been kept in a refrigerator, and that seems sweet, may have in it a stock of bacteria, and after we drink the milk the heat of our bodies favors their development. If milk is heated to 160° or 170° F., any germs of tuberculosis present will be

killed. Boiled milk is less readily digested, and it is not necessary to boil it to kill most kinds of germs that it may contain.

Summary. — 1. Dust as mere dry, dead matter is irritating.

2. Disease germs may form part of the dust of the air.

3. Most of our contagious diseases are known to be due to bacteria.

4. Burning is the surest method of destroying germs.

5. Carpets, tapestries, and cloth-upholstered furniture add largely to the dust in houses.

6. Putrefaction is caused by bacteria.

7. Preservation of food depends on destroying, excluding, or retarding the growth of the bacteria of putrefaction.

Questions. — 1. Is the air in the mountains or on the seashore better than elsewhere?

2. What regions are recommended for consumptives? Why?

3. How is milk sterilized?

4. Why do people seldom take cold while "camping out"?

5. Why are the "steel grinders," in factories, short-lived?

6. What occupations should be avoided by one who is predisposed to consumption?

7. What are some of the occupations suitable to those predisposed to consumption?

CHAPTER XIII.

EXCRETION.

The Formation of Waste Matter in the Body. — All the force, or energy, of the body is produced by oxidation in the tissues; thought by oxidation in the brain; motion by oxidation in the muscles; and heat, wherever oxidation goes on. This oxidation produces waste matter in our bodies just as we have seen that oxidation in a stove produces waste matter.

The Need of Removal of Waste. — When we waken on a cold winter morning we are likely to find that the fire in our hard coal stove has burned low. Not enough heat is given out. What is the trouble? Is it merely that more coal is needed? We put another hod of coal in the magazine (though usually some remains). Does this bring the desired result? No. We open the draft. Is this sufficient? It is not. We must shake down the grate and clean out the clinkers. The removal of waste is as necessary as the addition of a fresh supply of fuel. In this case more necessary, for no amount of fuel will do any good so long as the ashes shut off the draft. In our bodies the removal of waste is still more important, because waste matter not only clogs the system, but, if present in any great amount, acts as a poison to the tissues.

The Skin throws off Waste Matter. — The skin is constantly throwing off waste matter called sweat, or perspiration.

Experiment to show Insensible Perspiration. — Thrust the hand into a cold glass jar. Note the moisture that soon gathers on the inside of the jar from the insensible sweat of the hand. A common fruit jar will do for a small hand, but a candy jar is better, having a larger mouth and clear glass.

The Structure of the Skin. — The skin has two layers, the inner, or dermis, and the outer, or epidermis. The epidermis is thick over the palms and soles; elsewhere it is thin. The skin is much thicker than we would naturally suppose, and makes one fifteenth of the weight of the body.

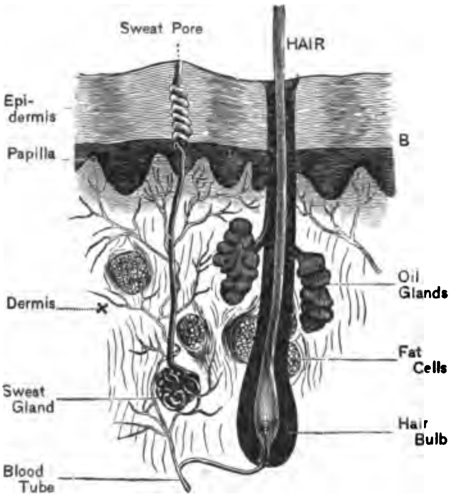


Fig. 64. Vertical Section of the Skin.

The Epidermis. — The epidermis consists of many layers of cells packed closely together. The deepest cells may be compared to grapes with their cell walls plumply filled out with the liquids of the cell. Suppose for the inner layer, grapes set on end, and so closely packed together as to press each other more or less flat on the sides. Above these are cells less closely pressed, more nearly spherical; then cells with less liquid in them, and somewhat shrunken, like raisins. Then still dryer cells flattened parallel with the surface of the skin. And, last, in the outer part, layers of cell walls, dry and empty, pressed flat like empty grape skins. These flat cell walls come off

in flakes (those from the scalp are called dandruff) from all the surface of the skin, and new cells are continually formed in the deeper layers.

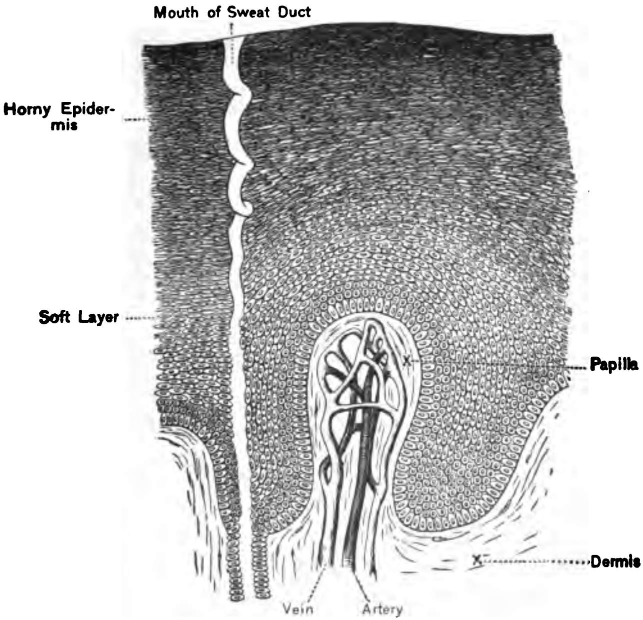


Fig. 65. Section of Epidermis, showing Papilla. (Highly magnified.)

The Color of the Skin. — The coloring matter, or pigment, of the skin lies in the deeper layer of the epidermis. In albinos the pigment is wanting. In persons with fair skin it is small in amount, in dark skins more abundant. Where the pigment is scattered irregularly it causes freckles, etc.

A Blister. — A blister is caused by separating the outer, harder layer of the epidermis from the inner, softer, darker layer of the epidermis, as at B, in Fig. 64. Serum, or blood, fills the space between the separated layers.

The Dermis. — The dermis consists chiefly of tough, interlacing fibers. Hence the strength and durability of leather, which is the dermis preserved and prepared. The epidermis is usually removed in tanning. The dermis is richly supplied with blood capillaries and lymph capillaries, but the epidermis has neither.

Papillas. — The outer surface of the dermis has many conical elevations, each of which is called a *papilla*. Over most of the skin they do not show on the outer surface, as the epidermis fills in the spaces between them, but is, itself, smooth on the outside. On the palms and soles the papillas are in rows, and these rows are indicated by the ridges.

Hairs. — Hairs are outgrowths of the epidermis, but are deeply embedded in the dermis. They are supplied with blood at the tip of the root, where the growth takes place. The exposed part of the hair does not contain blood and is not sensitive. (See Fig. 64.)

Hair-muscles. — There are small muscles connected with the roots of the hairs, by which the hair may be slightly moved. In the lower animals this power is much more used, as when the hair is made to stand erect on the back or tail of an angry cat or dog. The action of these muscles when frightened is what gives a peculiar feeling in the scalp, and to express strong fright we say, "It made his hair stand on end."

Oil Glands. — The oil glands of the skin are distributed over all the surface except the palms and soles. The oily matter is usually poured out around the hairs as they emerge from the skin; but some of the ducts open on the skin away from a hair. The oil serves to soften the skin and hair and keep them from becoming too dry. (See Fig. 64.)

Nails. — The nails, like the hair, are outgrowths of the epidermis. At the base the nail is supplied with blood, and here it grows. It is alive, hence this part is called the *quick;* but at the outer surface and the tip it is dead.

Examination of the Skin with a Lens. — Place a linen tester, or other hand magnifier, over the palm, and note the sweat pores or openings of the ducts of the sweat glands. Count the pores within the square shown. Measure this square, and then estimate the number of sweat glands to a square inch of the palm.

The Sweat Glands. — The sweat glands are minute tubes whose inner ends are closed, and whose outer ends open upon the surface of the skin. The tube going inward pursues a corkscrew-like course through the epidermis, then becomes straighter, and is coiled up in a ball in the deeper layer of the dermis, or, more often, in the connective tissue just beneath the skin. (See Fig. 64.) The cells forming the walls of the coiled part are different from those of the duct, or straighter part of the tube. As the blood flows through the capillaries of the skin it gives off lymph. In this lymph are waste matters brought from the muscles and other tissues that have been at work. The sweat glands absorb this waste matter, with considerable water, and pass it out to the surface.

Composition of Sweat. — Sweat is mostly water. About one per cent is solid matter, including salt and certain matter which like the organic waste matter from the lungs, easily putrefies. Sweat varies greatly in its wateriness and hence in the *relative* amount of solid matter contained. Ordinarily the sweat is evaporated as fast as it is poured out. In distinction from this insensible perspiration, there is the sensible perspiration — when it accumulates enough to be seen. These are not two kinds of sweat, but it is convenient to distinguish between the visible and the invisible.

The Amount of Perspiration. — There is about one quart in twenty-four hours. It varies with (1) The temperature and dryness of the air. (2) The condition of the blood, *e.g.* if watery from drinking much water. (3) Muscular exercise.

Gland Action and Blood Supply. — The sweat glands, like all glands, are largely dependent on the amount of blood supply. In exercising, the skin is usually redder from the greater supply of blood, and at the same time the glands are more active, for during exercise and for some time afterward there is more waste matter to be thrown out.

Control of the Sweat Glands. — But the activity of the gland is not a mere filtering process; it is not always in proportion to the amount of liquid present. There may be a cold sweat, *i.e.* when the skin is pale. This usually is due to excitement or emotion, which shows that the action of glands is under the control of the nervous system.

Sweat Glands are Excretory. — The sweat glands rid the body of certain waste matters, and are therefore called *excretory glands*. A sweat gland is a simple gland.

Distribution of Sweat Glands. — The sweat glands are thickly distributed over the whole surface of the body, but are especially numerous and large on the palms and soles. In the armpits the glands are also large.

Regulation of the Temperature of the Body. — It is a very striking fact that, except in disease, the temperature of the body varies only a little from 98.5° F. in winter and summer, during exercise and rest. The rate of producing heat varies greatly. The rate of giving off heat must therefore vary accordingly.

The Body gives off Heat. — In considering the regulation of the temperature of the body, we must bear in mind that the body is surrounded by air that is almost always considerably cooler than itself. The body is therefore almost always giving off heat. Our clothes do not warm us; we warm them, and they keep us from warming the air too fast, *i.e.* they keep us from losing too much heat. Indoor air in winter should be kept at about 68° F. by artificial heat. This air does not warm us; we, being about 30° F. warmer, are warming it.

Ways of giving off Heat. — The skin gives off heat by —

1. *Radiation:* heat is given off in every direction.

2. *Conduction:* whatever we touch that is cooler than our bodies is warmed. We warm chairs, clothing, etc.

3. *Convection:* the air in contact with the skin is warmed and rises. Our bodily heat is thus carried off by convection.

4. *Evaporation:* the evaporation of sweat is the most important factor in regulating the heat of the body. Any liquid in evaporating absorbs heat. The cooling effect of alcohol, ether, or cologne on the skin is due to the fact that heat is taken from the skin in converting the liquid into a gas.

Experiment in Evaporation. — With a medicine dropper put a drop of cologne on the back of the hand. Note two facts: (1) it produces a cooling effect; (2) the liquid quickly disappears.

Practical Applications of this Principle. — We sponge a feverish patient to reduce his temperature. The cooling effect is due not so much to the coolness of the water itself as to the absorption of heat from the skin in evaporating the water. We sprinkle the floor in hot weather and thus cool the air of the room.

Heat and Exercise.—When we exercise we produce more heat; we sweat more; more heat is taken from the body to evaporate this sweat. If we are not exercising and are in cooler air, we sweat less, and less heat is given off. When we exercise there is more blood in the skin, and more heat is given off by radiation, convection, and conduction. When we exercise less, the skin, especially in cool air, is paler, *i.e.* has less blood in it, and heat is economized. Thus the temperature of the body is kept uniform.

Distribution of Heat in the Body.—If more heat is produced in one part of the body than in others, the circulation of the blood tends to equalize the temperatures of the different parts. So, too, if one part is cooled, *i.e.* is losing heat faster than others, the blood brings heat from other organs to that part. If the hands and feet are exposed to cold, it may do little good to have the rest of the body well covered. A pair of wristers and a pair of leggings may often add more to one's comfort than a heavy overcoat.

Regulation of Temperature by Clothing.—In cold weather we put on more clothing and select non-conductors of heat, as woolen, leather, and fur. Many authorities recommend light woolen for summer wear, since with it we do not cool off so rapidly.

Regulation of Temperature by Food.—In cold weather we eat more. We also eat more fat and other heat-producing foods.

Effect of Wet Clothing.—In getting the clothing wet the cooling effect is not so much from the temperature of the water as from the loss of heat in evaporating the water from the clothing; and this goes on for a long time. Of course it is desirable to put on dry clothing as soon as

possible. It is dangerous to sit down in wet clothing, even on a warm day. Children seldom take cold from wading, even in cold water, if barefooted; but with wet shoes and stockings they are likely to take cold.

Mechanical Protection by the Skin. — This is the most evident function of the skin. The skin is tough, strong, and elastic, hence well fitted to cover the body and yield with every motion, yet protect the softer and more delicate tissues beneath it from injury.

Absorption by the Skin. — The skin has slight power of absorption; hence there is some danger in handling certain poisonous substances. The chief danger, however, is when there are cracks or sores on the hands. If one must handle suspicious material, it is well to rub the hands with vaseline. To use rubber gloves is safer still.

Review of the Functions of the Skin. — (The skin as a sense organ will be considered later.) 1. Sensory. 2. Heat-regulating. 3. Absorptive. 4. Protective. 5. Excretory. It will be easy to remember these five functions if it is noted that their initials spell the word s-h-a-p-e.

Skin-grafting. — Sometimes after extensive burns, or other injury of the skin, bits of skin are taken from another part of the body, or from another person, and transplanted to the injured part, where they grow.

External Features of the Kidneys. — The kidneys are a pair of bean-shaped bodies attached to the dorsal wall of the abdomen. (See Fig. 32.) The spot corresponding to the stem-scar of the bean is called the *hilum*. At this point are three tubes, the artery by which blood enters the kidney, the vein by which the blood leaves, and the ureter, by which the urine is conveyed to the bladder.

The Blood-supply of the Kidneys. — On entering the kidney the renal artery divides and subdivides, forming a very complicated set of capillaries. Through the thin walls of the capillaries certain waste matters pass into the cavity of the kidney, from which they are conveyed by the ureter to the bladder. (See Fig. 32.)

Urea. — Urea is the nitrogen-containing waste of the body. There is nitrogen in muscle, brain, and in all the important organs of the body. When they work, some urea is formed. If the urea accumulates in the blood, it acts as a poison to the tissues.

Importance of the Work of the Kidneys. — The kidneys are the only organs that can remove the urea from the blood; hence their great importance. Small as they are, their removal would soon cause death. Urea is a solid, and could not very well be carried out of the body unless dissolved. So the urine consists mainly of water containing urea, salt, and various other substances in small amounts.

Relation between the Kidneys and the Skin. — There is a very close relation between the kidneys and the skin. In warm weather, and when exercising actively, we sweat more and the kidneys excrete less water; on the other hand, when we exercise less, and especially in a cool place, we sweat less, and the amount excreted by the kidneys is increased. For instance, when one has a cold he is more or less feverish; that is, the action of the skin is interfered with, and there is less perspiration. At such time the kidneys have more work to do, and may be so overworked as to injure them permanently.

Summary. — 1. When the body works it produces waste matter.

2. Waste matter must be removed or it will poison the body.

3. The skin throws off sweat, — mostly water carrying waste matter.

4. Sweat is taken from the lymph by the sweat glands, which are coiled tubes, opening on the surface of the skin.

5. The skin consists of two layers, the dermis and the epidermis.

6. The amount of sweat varies with heat, exercise, food, etc.

7. The body gives off heat by (1) radiation, (2) conduction, (3) convection, (4) evaporation.

8. The temperature of the body in health stays at about 98.5° F.

9. The temperature is regulated by the evaporation of sweat.

10. Heat is distributed through the body by the blood.

11. In cold weather we eat more fat, and other food, to make heat.

12. The skin has five functions: touch, heat-regulation, absorption, protection, excretion.

13. The kidneys remove urea from the blood. Urea is the nitrogen-containing waste of the body.

14. If much urea is in the blood, the body is poisoned, and the removal of the kidneys would soon cause death.

Questions. — 1. Do dogs, cats, and cows sweat?

2. Why is thirst relieved by moistening the skin?

3. Why is it a good sign when the skin of a feverish person becomes moist?

4. Why should clothing worn during the day be removed at night?

5. Can food, medicine, or poison be absorbed through the skin?

CHAPTER XIV.

all

FOODS AND COOKING.

Necessity of Food. — Thus far we have been studying processes by which the body's weight is reduced. We have studied the oxidation in the tissues and the removal of the wastes. Unless the tissues receive a supply of new material, the heat and energy of the body cannot long be kept up.

Food Defined. — Foods are substances that build tissues or produce energy without injuring any organ or function of the body. Certain substances that do not become part of any tissues, nor in themselves produce energy, are useful in aiding the processes going on in the body. These may be called *accessory* foods, *e.g.* condiments, such as pepper.

Foods and Foodstuffs. — Most of our articles of food consist of two or more different kinds of materials. For instance, milk consists (1) chiefly of water; and in it are (2) the substance that makes cheese (casein); (3) cream, from which we get butter (fat); (4) sugar, which gives milk a sweet taste; (5) salts, such as common salt, lime salts, etc. These different materials are *foodstuffs.* We have many kinds of foods, but few foodstuffs, which we find occurring over and over again, in various forms, in the numerous things we eat.

Kinds of Foodstuffs. — 1. Proteids (example, casein).
2. Fats.
3. Carbohydrates (starch and sugar).
4. Water.
5. Salts.

The Proteids. — The chief substance in the white of an egg is albumen, a typical proteid. Of the many proteids some of the more commonly known are casein (the curd of milk), gluten (in grains), legumin (in peas and beans), fibrin (in blood), myosin (in muscles). Gelatin (obtained from connective tissue and bones by prolonged boiling) differs considerably from the proteids in composition, but may be counted in with them. It is less valuable as a food than the true proteids, although in certain circumstances more desirable from the fact that it is very easily digested.

Importance of Proteids. — The proteids are of special importance as foods because the most active tissues — those of the muscles, nerves, and glands — and the most important liquids of the body, *e.g.* blood and lymph, contain proteid. Proteid food, therefore, must be taken to make good the losses of these tissues during their oxidations. Proteid is the only foodstuff containing nitrogen.

Proteid-containing Foods. — The principal proteid-containing foods are lean meat, fish, eggs, milk, cheese, and some seeds which abound in the vegetable proteids.

Meat. — Lean meat has about twenty per cent of proteid, the rest being chiefly water. Beef and mutton are more easily digested than veal and pork. Pork sometimes contains a parasitic worm called *trichina*, which causes illness, or even death, if eaten. Pork should be thoroughly cooked so as to kill the trichinas.

Fish. — Fish, when fresh, is a good food. Although, as a rule, salted meats are less easily digested than fresh,

salted codfish is a nourishing and economical food. Fish is not an especially valuable brain food, as commonly believed.

Eggs. — Eggs contain considerable proteid, but their value as food has been overrated. The yolk has a large amount of fat. Although the egg has all the material needed to form a chick, it is not a perfect food for man.

Milk. — Milk, as we have seen, is an ideal food, in that it contains all the kinds of foodstuffs, and in the right proportion for the young mammal. But the proportions are not right for the adult. An adult would need four quarts and a half daily, and then he would not get enough carbohydrates (represented in milk by the sugar). The oily material in milk is in the form of minute globules, which can easily be seen under the microscope. Each of these oil droplets is surrounded by a thin envelope of albumen, by means of which it is enabled to remain suspended for some time instead of rising quickly to the surface. Such a mixture of oil in a liquid is called an emulsion. When cream is churned the albuminous covering is removed and the butter "gathers."

Cheese. — Cheese is very rich in proteid, much more so than lean meat. Yet, as it is hard to digest, we do not use it much as food; we regard it more as a luxury, while in many parts of Europe it is largely used as food, taking the place of meat. It is a cheap food, and might well be used more extensively, especially by laboring men. When taken with milk, it is said to be more readily digested.

Vegetable Proteids. — Peas and beans (dried) contain as much proteid (legumin) as meat, and all the cereals contain some proteid (gluten).

Fats.—Fats are composed of carbon, hydrogen, and oxygen. The oxygen is small in amount, so these foods yield a great amount of energy by the oxidation of their carbon (forming carbon dioxid) and hydrogen (forming water). The fats most used are animal fats, including butter. But some vegetable oils, such as olive and cotton-seed oils, are used.

The Carbohydrates.—Stareh and sugar are the chief carbohydrates. They are composed of carbon, hydrogen, and oxygen, but not in the same proportions as in fats. Starch is used in larger quantity than any other foodstuff except water. Sugar is usually regarded as a luxury, yet it is an important food. It is quickly absorbed.

Carbohydrate-containing Foods.—The principal carbohydrate-containing foods are the grains, vegetables, and fruits. The most important grains are wheat, corn, rice, oats, rye, and barley.

Wheat.—Wheat furnishes the principal breadstuff among the more civilized nations. It is especially adapted to the temperate zones. Taking into consideration its composition, digestibility, and other characteristics, it is the most desirable of all the grains.

Wheat Flour.—In ordinary white flour nearly all the gluten has been removed with the bran or "middlings." While wheat or bread made from the whole grain of the wheat may support life, one would starve if he tried to live on common white bread alone. It is almost entirely starch. In the "entire wheat flour" it is claimed that all the gluten is retained, only the very thin outer husk of the grain being removed. It does not make so white a flour, but it is better adapted to use as a food. If we use white bread, having thrown away the nitrogenous part of the wheat, we need to

take more proteid from other sources than if we used the entire wheat flour. This is not economy. It is claimed that the entire wheat bread is more wholesome as well as more nutritious. The part thrown away has in it phosphates as well as the nitrogenous material. This flour is ground fine so that it has not the coarse particles which are in Graham flour, and which are, in some persons, a source of irritation to the mucous coat of the digestive tube.

Corn. — Corn is one of the most nutritious of the grains. Although somewhat less readily digested than similar preparations of wheat, and, consequently, less desirable for indoor workers, it is a fact that, for a given amount of money, more nutriment can be obtained in corn meal than in any other food known.

Rice. — Rice forms a larger part of human food than the product of any other plant, being often an almost exclusive diet in India, China, and the Malayan islands. Rice has a larger proportion of starch, and less of fats and proteids, than the other grains. It is best adapted for the food of warm climates.

Oats. — This grain was first used as food for man by the Scotch, but the use has extended and become prevalent in this country. In point of nutrition it is ranked higher by some than ordinary grades of wheat flour.

Rye. — Rye grows farther north than other grains, and is largely used for bread in Russia and parts of Germany. It is a valuable food, though less nutritious and less digestible than the corresponding preparations of wheat.

Barley. — This grain has wide range of cultivation, and, while inferior to wheat, is considerably used where other grains cannot be raised.

Potatoes. — Potatoes contain about twenty per cent starch, two per cent of proteid, and no fat, the remainder being chiefly water, with some useful salts, especially potash salts. In spite of its relatively low food value, the potato is our most useful vegetable on account of its abundance, the ease with which it can be preserved, and the readiness and the variety of ways in which it can be cooked.

Other Vegetables. — The chief nutrient in vegetables is starch, though in many the starch is present in small amounts. The salts and acids present are of value, and care should be observed not to remove too much of these salts in cooking. The fibrous matter, cellulose, while indigestible, is of value in adding bulk to the mass of food to be digested.

Scurvy. — Formerly sailors were subject to scurvy; this is now attributed to a diet of fat and salt meat, to the exclusion of fresh vegetables, etc. The disease is avoided by a greater use of vegetables, lime juice, etc.

Fruits. — Many of the fruits, such as bananas and apples, have considerable starch and sugar. But the fruits are more useful to us on account of their flavor, due to aromatic bodies, and to their salts and the peculiar fruit acids.

Water. — Water constitutes about two thirds of the entire weight of the body. It constitutes the bulk of the liquids we have studied, blood, lymph, sweat, saliva, bile, etc. Water dissolves and carries all the material of the body. Hence we need a large amount of it; of course we must remember that we get a good deal of water in most of our solid foods.

Rain Water. — Water, as it comes from the clouds, is pure. After enough rain has fallen to wash the air, rain

water is pure, and if caught on a clean roof (especially a slate roof) and kept in a clean cistern, it is good drinking-water.

Well Water. — Falling upon the earth, the rain water filters down until stopped by some layer, such as clay, through which it cannot soak. This water is the supply of our wells and springs. It always has more or less earthy matter, especially lime, in solution, and is therefore more or less "hard." Unless a large amount of mineral matter or some special material is dissolved in it, it is ordinarily good drinking-water. Such water is not pure, in the strict sense of the word, but is pure for drinking purposes.

Impurities in Water. — The great source of danger is from what are called "organic" impurities. Bacteria do not thrive in pure water. They must have something on which to feed and grow. But in water containing a large amount of decaying animal or vegetable matter they are likely to abound. And the most dangerous sources of contamination are cesspools and sewers. Water may be contaminated by such material and not have bacteria in it, but is very likely to harbor such foes.

Contamination from Cesspools. — The ordinary cesspool is a grave source of danger. Because the well may be on higher ground than the cesspool does not give assurance that the water may not be polluted. Often when the surface of the ground slopes in one direction, the strata underneath may slope in the opposite direction, and the well may be the reservoir into which the cesspool is drained. Good authorities say that a cesspool should not be allowed within a hundred feet of a well.

Abolish the Cesspool. — It is better and safer to have no cesspool. Where a sewer system is not to be had, it is better to allow no great accumulation of such material. A deep pit in which a quantity of semiliquid matter gathers is not only a nuisance but a source of danger. Privies should have a very shallow pit, or none, and should be cleaned often. There should be a little dust sprinkled in each day, and occasionally some chlorid of lime or sulphate of iron.

Typhoid Fever. — Typhoid fever is usually caused by drinking-water. The excretions of some one who has had the disease find their way into the source of the drinking-water. In many cases this has been clearly proved. Of course the excretions of all such patients should be either destroyed or thoroughly disinfected.

Ice Water. — Although bacteria will not develop in a cold place, they are not killed when frozen in ice, as was formerly supposed. Further, ice, in forming, does not throw out all the impurities, as was formerly believed. So it is not safe to drink water formed from melted ice unless the water of which that ice was made was good water. The ice taken from ponds is not safe. If ice is made artificially from suitable drinking-water, the melted product will be essentially unchanged so far as the composition is concerned. Water may be cooled by placing any ice around it, and we may have the desired temperature without danger.

Boiling Water. — When one cannot get good drinking-water, or when away from home where the water is of doubtful purity, it is better to boil the water before using it, either as a drink or in preparations of food that are not to be thoroughly cooked. It seems to be proved that it is

better to heat the water twice nearly to the boiling point than to boil once only. The first heating may start the germs into more active life, causing them to sprout (so to speak), and a *second heating several hours later* may easily kill them; whereas it has been proved that one hard boiling will not always kill the germs.

Cautions as to Drinking-water. — If one uses tea and coffee, it is safer to content one's self with these, and not drink much water till that which is safe, as from deep wells, can be obtained. In hot weather, and especially for those who are engaged in hard work, it has been found that a little oatmeal stirred in the water is beneficial. When overheated, avoid drinking much cold water. Repeatedly rinse the mouth with cool water, and swallow very little. This is the way trainers manage a horse at a race, and it is sensible to treat a man as carefully.

Salts. — Salts include many substances besides common salt. They aid in the solution of various substances during digestion and in other processes. We cannot live without them. Lime in the form of calcium phosphate and calcium carbonate is essential, especially in the bones and teeth.

Necessity of a Mixed Diet. — Our experience, together with the results of experiments on animals, teaches that we could not live long if fed on any one class of foodstuffs alone. We must take a representative of each of the groups. We have noticed that most of our foods already contain more than one foodstuff. We so combine them as to get suitable proportions. Thus we eat bread and butter (a small amount of fat with a large quantity of starch and a little gluten), meat and potato, crackers and cheese, pork and beans, egg on toast, bread and milk, rice

and fowl, macaroni and cheese; they "go well together" chiefly because each contains what the other lacks.

Disadvantages of a One-sided Diet.—In order to get enough nitrogen from bread alone, one would have to eat about four pounds a day; meanwhile twice as much carbon as is needed would be taken, thus throwing an undue amount of work upon the digestive organs. Again, one would need to consume about six pounds of meat to get the requisite amount of carbon, and six times as much nitrogen as is needed would be taken; to get rid of this extra nitrogen would severely tax the kidneys and liver.

Effect of Cold on Appetite for Fats.—In cold climates a large amount of fat is consumed, while in the tropics starch is the chief food. Our appetites call for more of the fatty foods during the winter season.

Proper Diet.—While common experience has led people to adopt a mixed diet, the proportions of the different foodstuffs is not always what it should be. The proportions of the foodstuffs (exclusive of water) may be roughly stated as about 1 part of proteid, 1 part of fat, 3 parts of carbohydrates. But this will vary somewhat with the amount of work done, and other varying conditions.

Vegetarians.—The so-called "vegetarians" recognize the need of proteid food, and most of them seek proteid in eggs, milk, and cheese. But these are animal products, and the name "vegetarian" is inconsistent. They are merely "anti-meat eaters." That we are adapted for using flesh as part of our food is indicated in at least two anatomical features: (1) we have canine teeth, though not so fully developed as in the carnivora; (2) the intestine in carnivora is very short, that of the herbivora very long,

but in man intermediate. Nevertheless, it is undoubtedly true that many persons eat too much meat.

Beef Tea. — Beef tea and various beef extracts are helpful. There is not enough nourishment in them to maintain strength without other food. But many of the soups and drinks made from them are beneficial. They refresh the tired system wonderfully. If the man who feels "fagged out" and takes a drink of liquor to "brace him up," as he says, were to take a cup of hot bouillon, he would find himself "braced up," for the time, without any bad reaction, or permanent injury to the system.

Cooking. — Cooking is designed to make food more palatable and more digestible. Some foods, such as eggs, are as digestible before they are cooked as after. But many foods in the raw state are unattractive, whereas cooking usually develops an agreeable odor and taste. Cooking should soften the harder and tougher tissues, such as cellulose in vegetables and the connective tissue of animal foods. Cooking starch causes the starch grains to swell and burst, and makes the starch more digestible.

Making Soup.—If meat be cut into small pieces and put into cold water, and the water gradually warmed, the soluble material of the meat may be extracted, and this is the principle followed in making soups.

Boiling Meat. — If we wish to cook the meat itself, the juices should be retained instead of withdrawn. For this purpose boiling water is poured over the meat to coagulate the outer layer and prevent the extraction of the juices.

Baking, Roasting, and Broiling. — The same principle applies to baking, roasting, and broiling. The outside is subjected to high heat at the beginning of the cooking, which forms a sort of crust through which the nutritious

juices cannot escape. In these modes of cooking it is very desirable to reduce the heat after the first few minutes, so that the interior may be cooked enough without over-cooking the outside; this is especially true in broiling.

Frying. — Frying, as ordinarily done, is not a good mode of cooking; in fact, is often very bad, as the food is frequently soaked with fat and rendered indigestible. But true frying, that is, by immersion in boiling fat, is a good mode of cooking. This coagulates the albuminous substance on the outside, keeps in the nutritious juices, and prevents soaking with the fat.

Summary. — 1. Food is to build tissue or produce energy.

2. Foodstuffs are the simpler materials in foods.

3. The foodstuffs are proteids, fats, carbohydrates, water, salts.

4. The proteids are albumen, casein, gluten, legumin, fibrin, myosin, gelatin.

5. They are found in meat, egg, milk, peas, beans, and a little in grains.

6. The carbohydrates include starch and sugar.

7. Starch is obtained from potatoes and the grains.

8. The most important grains are wheat, oats, corn, rice, and rye.

9. Wheat is considered the best grain, though more nourishment can be obtained from corn meal, for a given amount of money, than from any other food.

10. Vegetables contain some starch, but are of value from giving bulk to the food.

11. Water containing decaying organic matter is dangerous to drink, because it is likely to contain bacteria, which poison us or cause disease.

12. Boiling water usually kills the bacteria in it.

13. Drinking ice water is injurious.

14. We take a mixed diet, as no one food contains all we need.

15. Cooking is to render food more palatable and digestible.

Questions. — 1. Is the appetite always a safe guide in eating?

2. Which kind of foodstuff is most expensive? Why?

3. Why is bread the "staff of life"?

4. Make a list of the common foods, naming the foodstuffs in them.

5. How do flour and potatoes compare in cheapness?

CHAPTER XV.

THE DIGESTIVE SYSTEM.

DIGESTION IN THE MOUTH.

The Object of Food. — The tissues are worn out by their oxidation. They are built up again by the blood, and the blood is renewed by the food.

The Digestive Tube. — All food must be reduced to the liquid condition, if it is not already liquid. The chief organ in this work of liquefying the food is the *digestive tube*, or "alimentary canal." As the food passes through the digestive tube it is ground and liquids are poured upon it. Thus it is reduced to a liquid that can be absorbed and taken into the blood.

The Work of the Digestive Tube. — To take a special instance, a muscle is in part worn out by the oxidation during its activity; to replace the loss suppose we take a piece of steak. We cannot substitute this directly in the place of the worn-out tissue. In digesting the steak we must tear it to pieces, and reduce it to a liquid form by the action of the teeth and by the various liquids from the glands along the digestive tube. The beefsteak, as such, must be thoroughly destroyed; in the liquid produced by the digestion of the beef there is no trace whatever of the structure of the beef. But the blood, taking this material, builds muscle which can hardly be distinguished from the original beef.

If the food taken is a liquid and ready to build tissue, as a thin syrup, it will not need to go through these changes.

The Organs of Digestion.—The organs of digestion are the digestive tube, with the masticating organs, and the glands in and along the walls of the tube.

The parts of the digestive tube are the mouth, the pharynx, the gullet (or esophagus), the stomach, the small intestine, and the large intestine.

The Mouth and Gullet.— At the back of the mouth may be seen the soft palate with the cylindrical uvula hanging from its center. Beyond this is the cavity of the pharynx, which narrows below into the gullet, a red-walled, muscular tube, extending along the back side of the windpipe, and close to the spinal column. It extends the length of the chest, and then passes through the diaphragm and widens into the stomach, at the upper left end of the latter.

The Stomach.—The stomach is somewhat pear-shaped, with the larger end to the left. At the right end it tapers into the small intestine, the first foot or so of which is called the duodenum. (See Figs. 53, 72, and 74.)

The Liver and Pancreas.—Just below the diaphragm is the dark-colored liver, overlapping a large portion of the stomach. Between two of the three lobes of the liver is the bile sac, whose duct enters the duodenum a short distance from the stomach. The pancreas is a pinkish organ of irregular shape lying along the stomach and duodenum. Its duct enters the duodenum at the same point as the bile duct.

The Intestine.—The first part of the intestine is the small intestine. At the lower right part of the abdomen

this enters the larger intestine. The intestine is held in place by the mesentery, a thin fold of transparent membrane folded closely around it, and supported from the back wall of the abdominal cavity. Between the two layers of the mesentery are the branches of the artery supplying the walls of the intestines, and the veins that convey the absorbed food from the intestine to the liver.

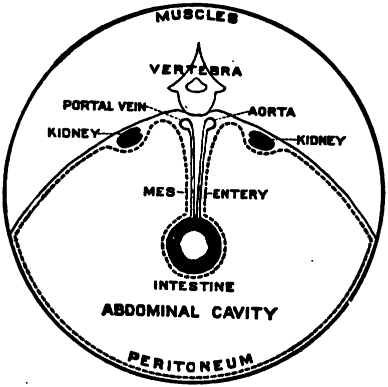


Fig. 66. Cross-section of Abdomen.

The Mouth. — The pupil should carefully examine his own mouth by means of a mirror. We are apt to think of the mouth as a cavity of considerable size, as indeed it is when fully opened; but we are not so likely to think how completely the cavity disappears when the mouth is closed. If one notes the sensations from the mouth when it is closed, he will perceive that the tongue almost entirely fills the space, touching the roof of the mouth, and the teeth in front and at the sides.

The Tongue. — The tongue consists chiefly of muscles, running in different directions, thus giving it a variety of motions. The tongue is the chief organ of taste, and is therefore (with the sense of smell) the gate-keeper of the digestive tube. The tongue has also a keen sense of touch, and so is useful in detecting and removing any food particles that may remain on the teeth after eating. During mastication the tongue, with the lips and cheeks,

keep the food between the teeth. When the morsel of food is sufficiently masticated, the tongue pushes it back into the pharynx to be swallowed.

The Teeth. — The teacher can usually obtain a supply of teeth from the dentist for the asking. These should be cleaned before using them in the class. Use pearline or any washing soda. Let each pupil make a drawing of one of each of the four kinds of teeth; draw both a front (outer surface) and a side view (surface adjacent to another tooth) of all but a molar.

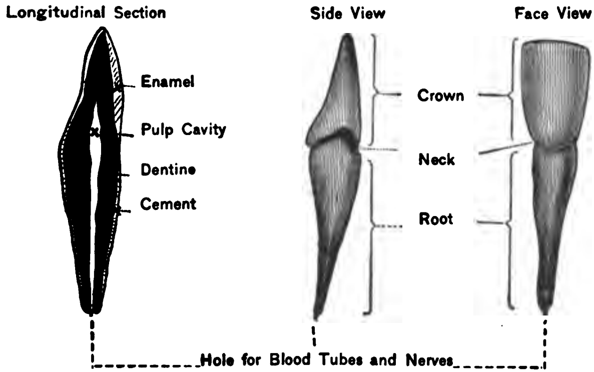


Fig. 67. Parts of a Tooth. (Incisor.)

External Features of a Tooth. — Examine one of the front teeth. It has the following parts: —

1. The crown, the part that is above the gum.
2. The root, the part that was buried beneath the gum.
3. The neck, dividing the crown from the root.
4. A hole at the tip of the root.

To make a Section of a Tooth. — Let each pupil prepare a longitudinal section of a tooth as follows: Embed a tooth in a little sealing wax on the end of a spool, cork, or block of wood. With a grindstone grind away one half, showing the pulp cavity to the tip of the root, as in Fig. 67. Make a drawing of the surface thus exposed, naming the

parts. **If human teeth cannot be obtained, almost any kind will serve. Let each pupil keep his preparation.**

Structure of a Tooth. — 1. The pulp cavity, communicating with a hole in the tip of the root, through which the nerve and blood tube entered.

2. The bulk of the tooth is made of a substance called dentine (ivory).

3. The crown of the tooth has a covering of enamel, a very hard substance.

4. The root is covered with a bony substance, called cement.

The Arrangement of the Teeth. — Beginning at the middle of the front of the mouth, there are (in the normal adult) eight teeth in each half jaw: two incisors, one canine, two bicuspids (or premolars), and three molars (see Fig. 68).

Dental Formula. — The kinds and arrangement of teeth are expressed by a dental formula, in which the numerators indicate the upper jaw and the denominators the lower, thus: $I\frac{2}{2}$, $C\frac{1}{1}$, $PM\frac{2}{2}$, $M\frac{3}{3}$ (for one side of the head).

The Kinds of Teeth. — The crown of an *incisor* is chisel shaped; but the root is flattened in the opposite direction, *i.e.* at right angles to the jaw, instead of parallel to it, as in the crown. The *canine* tooth has a conical crown, and a longer root than the incisor. The *bicuspid* has two points. The *molar* has a cube-shaped crown, and usually two or three roots.

The Milk Teeth. — The thirty-two teeth of the permanent set were preceded by a temporary set of twenty milk teeth. Because the first set is temporary, it should not therefore be neglected. Cavities in these should be filled and the teeth kept clean. Before the temporary set has

gone the first of the permanent set appear. The first of these, often called the "six-year molars," are just back of the hindermost "milk molars." These should receive especial care, as they will never be replaced. Any beginning of decay in them ought to receive prompt attention.

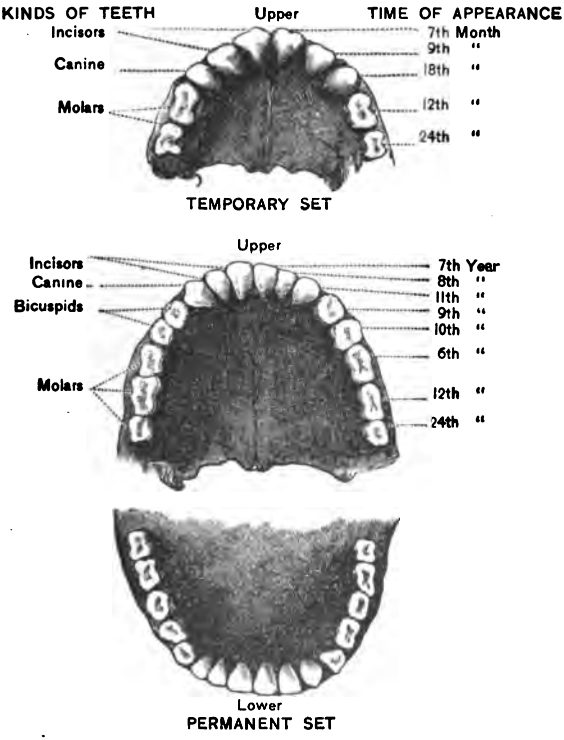


Fig. 68. TEETH: Kinds, Arrangement, and Times of Appearance.

The Care of the Teeth. — The teeth need careful attention. They should be thoroughly brushed at least twice a day, on rising and on going to bed. It would be better to clean them after each meal also. If a tooth powder, recom-

mended by a reliable dentist, is not used, a good white castile soap will serve well. It is better to use tepid water. Toothpicks are useful in removing the larger particles. Quill toothpicks are best; metal should never be used. The teeth should be examined twice a year by a dentist, and any cavities promptly filled.

Cause of Decay of Teeth. — If the teeth are not thoroughly cleaned the particles of food which remain will soon begin to decay. This decay is caused by the growth of germs, usually some kind of bacteria, and the decay thus begun is likely to develop acids which attack the limy material of which the teeth are composed. When it is necessary to take acid medicines, care should be taken not to let them come in contact with the teeth. Sweet substances are very likely to decompose and form acids; so we must clean the teeth after eating candies. When the teeth are neglected, a limy substance, called *tartar*, forms on them and encourages decay.

The Salivary Glands. — The salivary glands make the saliva and pour it into the mouth. There are three pairs of salivary glands — the parotid, just back of the angle of the jaw, under the ear; its duct opens on the inside of the cheek opposite the second molar of the upper jaw. The submaxillary gland lies under the angle of the jaw; its duct opens under the tongue near the front of the mouth. The sublingual gland is in front of the submaxillary and empties under the tongue (see Fig. 74).

Salivary Ducts in our Mouths. — If the inside of one's cheek be examined by the use of a hand mirror, the opening of the duct from the parotid gland may be seen opposite the second molar of the upper jaw. It usually looks like a pink and white spot, resembling a wound of a bee sting. Sometimes saliva may be seen issuing from it.

Action of the Salivary Glands. — The salivary glands pour into the mouth a liquid which they make from materials taken from the blood. In structure the gland may be compared to a bunch of grapes, the grapes representing the little cavities, with a wall of cells that make the saliva. From each of these cavities the liquid passes into its duct, represented by the stem of a single grape; many of these unite to form the main duct, which corresponds to the main stem. A thick network of capillaries

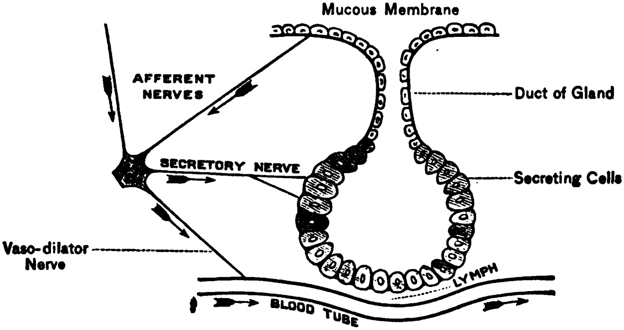


Fig. 69. Diagram of a Salivary Gland. (After Landois and Stirling.)

surrounds the gland; the liquid part of the blood (plasma) soaks out through the capillary walls and surrounds the gland; it is now called lymph; from the lymph the gland directly obtains its material.

Nerve Control of Salivary Glands. — The glands are doubly dependent on nerve control: —

1. Through the nerve control of the muscles in the walls of the arteries the amount of blood sent to the glands is regulated.

2. Nerves also go to the cells of the gland to control their activity. When we taste, smell, see, or even when we think of, some delicious food the mouth may "water,"

as we say, *i.e.* the salivary glands are, by reflex action, stimulated to activity; on the other hand, some emotions, such as fear, check the flow of saliva.

Saliva and its Uses. — The saliva is mostly water, and, when we are not eating, serves (1) to keep the mouth moist. The water of the saliva soaks the food during mastication and (2) helps the process of grinding; it (3) enables us to taste by dissolving any food that is soluble; it further (4) enables us to swallow what would otherwise be a dry powder. The special element of the saliva, *ptyalin*, has the power (5) of changing starch to sugar.

Amount of Saliva. — The amount of saliva secreted daily is estimated at three pints. Of course the glands should be allowed to rest between meals. The habit of chewing gum, though supposed to aid digestion, undoubtedly does far more harm than good. During the resting period the glands accumulate material for the active work of secretion, for there is no sac in which to store the saliva, and it must be made as fast as is needed.

Mucous Glands and Mucus. — Besides the salivary glands, there are great numbers of simple glands in the mucous membrane lining the mouth. These secrete a clear substance called mucus, resembling white-of-egg. It is mucus in saliva that makes it "stringy."

Mumps. — In the mumps the salivary glands are inflamed and painful. This is most noticeable in the parotid gland, which feels the pressure of the lower jaw in the attempt to chew.

Summary. — 1. The chief work of digestion is to make the food into a liquid, ready to be absorbed and become part of the blood.

2. The digestive system consists of a long tube, through which the food passes, being subjected to mechanical and chemical processes.

3. The parts of the digestive tube are the mouth, gullet, stomach, and intestines.

4. Along this tube are several large glands, such as the salivary glands, pancreas, and liver, which make liquids to pour upon the food.

5. The tongue is composed of muscles, is very movable, and (1) tastes the food; (2) keeps the food between the teeth during chewing; (3) aids in swallowing.

6. A tooth has crown, neck, and root.

7. The tooth consists of dentine, containing a pulp cavity. The crown is covered with enamel, and the root is covered with cement.

8. There are thirty-two teeth in a full set, eight in each half jaw, beginning at the front, two incisors, one canine, two bicuspids, and three molars. The first set of twenty teeth are called "milk teeth."

9. The teeth must be kept clean by brush and tooth powder.

10. There are three pairs of salivary glands, parotid, submaxillary, and sublingual. Their action is controlled by nerves.

11. The chief use of saliva is to change starch to sugar.

Questions. — 1. Why should we not crack nuts with the teeth?

2. Why does the physician examine the tongue of his patient?

3. Is it well to eat much soaked food? Why not?

4. How many teeth have you, and of what kinds?

5. Why is gum-chewing injurious?

CHAPTER XVI.

DIGESTION IN THE STOMACH.

The Pharynx. — The cavity back of the mouth, beyond the soft palate, is the pharynx. The pharynx is a funnel-shaped cavity, connecting above with the passages from the nostrils; in front it opens into the mouth; below it

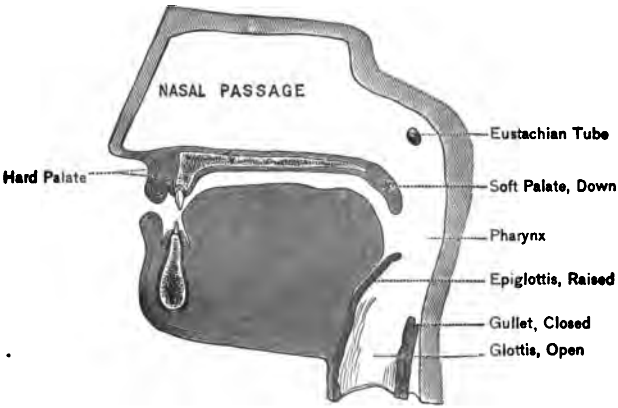


Fig. 70. Positions of the Organs of the Mouth and Throat during Breathing.

connects with the windpipe, through the glottis, and with the gullet, which lies just back of the windpipe (see Figs. 70 and 71).

Position of Organs during Respiration. — In quiet respiration the tongue nearly fills the mouth. The base of the tongue is nearly covered by the soft palate, which curves downward from the hard palate, and by the epiglottis projecting upward from below. The glottis is open and the

gullet is closed. Air enters the nostrils, passes along the nasal passages above the hard palate, back of the soft palate and epiglottis, through the open glottis into the windpipe, and on to the lungs.

The Process of Swallowing. — When the morsel of food is ready to be swallowed the tongue pushes it back into the pharynx; the soft palate is raised to shut off the passage into the nasal cavity; the epiglottis is pulled down

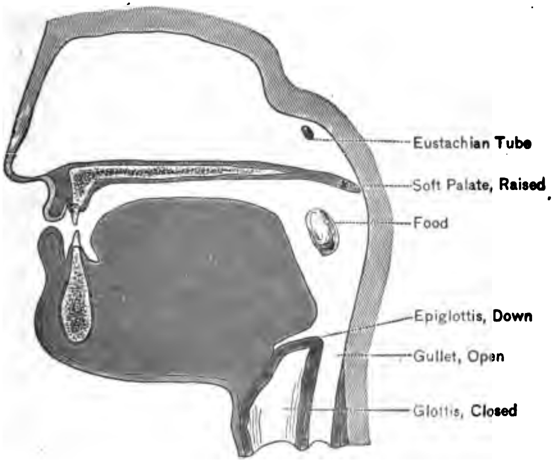


Fig. 71. Positions of the Organs of the Mouth and Throat during Swallowing.

over the glottis, or opening of the windpipe; and the base of the tongue extends back over the epiglottis; thus the air passages, above and below, are shut off, and the food passes over the epiglottis into the gullet. The muscles of the pharynx also do their part in pushing the food along. As soon as the food has passed over the epiglottis, the epiglottis rises to its upright position, and the soft palate drops back to its place, leaving the air passages again open.

Breathing and Swallowing. — It is to be observed that the food tube and the air tube cross, and that the pharynx is their crossing. As we are swallowing only a small part of the time, the passageway naturally stands open to the air; and when we swallow, the parts are, by muscular effort, temporarily arranged for this work. There is a spring switch (to borrow a term from the railway) which keeps the track open for the air, which is all the time passing; but when the food comes along, the switch must close the air passage and hold open the food passage until the food has passed.

Structure and Action of the Gullet. — The gullet has an outer muscular coat and an inner mucous coat (see Fig. 72). The muscular coat has two layers, an inner with circularly arranged fibers, and an outer layer with fibers running lengthwise. When the food enters the gullet the muscle fibers, cspecially thc circular fibers, shorten, and by a wave-like action push the mass rapidly along into the stomach. The first part of swallowing is voluntary; but after the mouthful has entered the gullet the action is involuntary. The mucous lining of the gullet has many mucous glands which make the passageway smooth by the mucus which they secrete.

Illustration of Passage through the Gullet. — The passage of the food through the gullet may be illustrated as follows: Let several persons hold a large rubber tube with their hands in contact. Put an egg-shaped piece of wet soap in the tube. The first hand is shut and pushes the soap along into the part of the tube held by the next hand; this hand now compresses the tube, while the first hand remains clinched; and so, in turn, the object is pushed the whole length of the tube.

The Stomach. — Just below the diaphragm the digestive tube widens suddenly, forming the stomach; the stomach

is an oval sac lying just beneath the diaphragm, with the large end to the left and the small end to the right. The smaller end, by narrowing, becomes the small intestine. When the stomach is empty it collapses, as its walls are soft and flexible. When distended it may hold three pints, or, when greatly distended, even more.

The Coats of the Stomach. — The stomach and intestines have four coats, in the following order, beginning at the outside: the peritoneum, the muscular, the submucous, and the mucous coats. The muscular coat of the stomach consists of three layers, distinguished by the arrange-

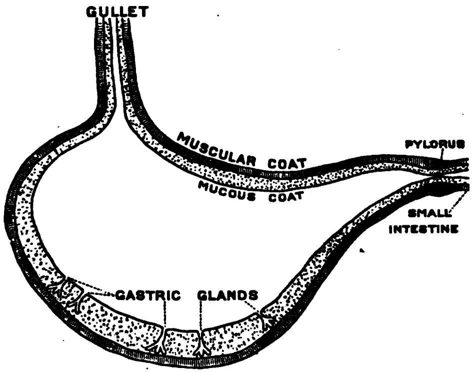


Fig. 72. Longitudinal Section of Stomach, showing Gastric Glands in Position. (Back View. Mucous Coat unduly Thickened.)

ment of the fibers, a circular layer, a longitudinal layer, and an oblique layer. The mucous lining is somewhat loosely attached to the muscular coat by the submucous coat between them, and when the stomach collapses, the mucous coat is thrown into folds, usually running lengthwise.

The Gastric Glands. — In the inner surface of the mucous membrane are many holes. These are the mouths of the ducts of the gastric glands. If a duct is traced inward, it is found to be either a simple tube (see Fig. 73) or to divide into branches, usually two or three.

The Gastric Juice. — The liquid secreted by these glands is called the gastric juice. The gastric juice is chiefly water, containing a substance called pepsin, and a small amount of acid. The amount of gastric juice secreted daily has been estimated at four or five quarts. Of course, we must bear in mind that nearly all of this is again absorbed from the digestive tube, and is not a loss to the body.

Blood Supply of the Stomach. — The mucous membrane is well supplied with blood-tubes, but while it is resting the blood flow is diminished, and it is pale. But as soon as food is introduced into the stomach the blood flow is greatly increased, and the mucous membrane becomes red. This blood supply gives the glands the materials with which they manufacture the gastric juice. At the same time the cells of the glands are stimulated to action, and the secretion is poured out rapidly. The saliva also aids in stimulating the secretion of the gastric juice.

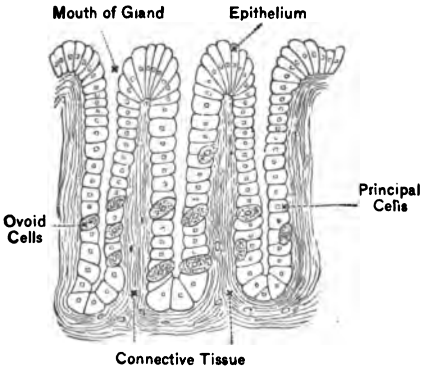


Fig. 73. Three Glands of the Stomach.

The Work of the Gastric Juice. — The special work of the gastric juice is accomplished by the pepsin, aided by the acid; these change proteids into a soluble substance, called peptone, which can be absorbed through the walls of the digestive tube into the blood.

Rennet and Rennin. — Rennet, used in cheese making, is a familiar substance obtained from the fourth stomach of the calf. When milk enters the stomach it is curdled; that is, the casein previously dissolved in the liquid milk is curdled. This curdling, or coagulation, is caused by a substance in the gastric juice called *rennin*.

The Action of the Stomach. — At the same time all the food is soaked by the gastric juice, the process being greatly assisted by the churning motion of the stomach caused by the action of the muscular coat. This muscular action of the stomach is called the peristaltic action. The food is thus gradually reduced to a pulpy mass called chyme. During the first part of digestion in the stomach the thick ring of circular fibers, called the pylorus (gatekeeper), around the opening from the stomach into the intestine, keeps the passage nearly closed, leaving a small hole for liquids only. But as the food is reduced to the proper condition the muscles relax and allow the chyme to pass into the intestine. And at last any indigestible substances are usually allowed to pass.

Sphincter Muscles. — Such rings of muscular fibers as the pylorus, guarding openings, are called sphincter muscles.

Time of Stomach Digestion. — The time required for the stomach digestion of a meal is from three to four hours, though this may be much longer if very indigestible substances have been eaten, or if the condition of the body or mind is such as to retard the process of digestion.

Chyme. — The rest of the food, now called chyme, is passed on into the small intestine. It is acid, and in a liquid or semiliquid condition. Chyme, as it enters the intestine, is a mixture of digested, partly digested, and undigested materials. Some of the starch has been changed

to sugar, but only a small part, owing to the short time of mastication. The bulk of the starch is unchanged. Some of the proteid is already changed to peptone. Part is still proteid, while part is in an intermediate stage between proteid and peptone. Fat is melted by the heat of the mouth and stomach, and is more or less divided into small drops by mastication and the movements of the stomach. For instance, in eating bread and butter, the melting butter will be finely mixed with the bread as it is chewed. The water in the chyme was partly taken as such, and partly derived from the saliva and gastric juice. There are also present ptyalin, pepsin, mucus, salts, and some indigestible substances. At intervals the sphincter muscles of the pylorus relax, and the contractions of the stomach send the liquid mixture into the intestines by spurts.

Heart-burn. — Heart-burn is a burning feeling in the stomach and lower part of the chest caused by indigestion. There is a fermentation in the stomach, usually producing an acid or sour stomach.

Summary. — 1. The pharynx opens into the mouth, nostrils, windpipe, and gullet.

2. In breathing, air passes through the nostrils and the pharynx, and enters the windpipe; the soft palate is down and the epiglottis is up.

3. In swallowing, food passes from the mouth, through the pharynx, into the gullet; the soft palate is raised and the epiglottis is pressed down, covering the opening into the windpipe.

4. Food is pushed along the gullet by the shortening of the ring-like muscles.

5. The stomach is pear-shaped, with the large end to the left.

6. The stomach has four coats, — serous, muscular, submucous, and mucous.

7. The gastric glands are tube-like pits in the mucous coat of the stomach. They make gastric juice.

8. The mucous coat of the stomach contains more blood during digestion, and is more red. than when resting.

9. Pepsin in the gastric juice changes proteids to peptones.

10. The muscles of the stomach wall give a churning motion.

11. The food is reduced to a thick liquid called chyme.

12. The stomach requires three or four hours to digest a meal.

Questions. — 1. Why is one more likely to choke if he thinks about the process of swallowing?

2. What are the peculiarities of a cow's stomach?

3. Why do athletes eat sparingly before a game?

4. How does indigestion sometimes make one short-winded?

5. Why is it uncomfortable to hold the organs in the "swallowing position"?

6, Why is it hard to swallow a pill? Why take water with it?

7. Try swallowing repeatedly. Why is it difficult?

8. How is the structure of the windpipe favorable. to swallowing?

9. Why is indigestion more noticeable in the stomach than later?

CHAPTER XVII.

DIGESTION IN THE INTESTINE.

The Parts of the Intestine.—The intestine consists of two parts: first, the long and narrow small intestine; second, the short and wide large intestine. (See Fig. 76.)

The Small Intestine.—The small intestine has essentially the same structure as the parts of the digestive tube already studied; namely, a muscular coat and a mucous lining. The muscular coat has two layers, one of circular and the other of longitudinal fibers. The muscular coat mixes the juices with the food and moves it along. The muscular action of the intestines is a slow writhing motion, called peristaltic action. The mucous coat supplies mucus, which keeps the surface soft and smooth.

The Liver.—The liver is just under the diaphragm. It is convex above, where it fits the hollow under surface of the diaphragm, and hollow below, where it fits over the upper surface of the stomach. The greater part of it is on the right, as the greater part of the stomach is on the left, side of the body. The liver is dark colored and of very delicate structure, chiefly because it has very little connective tissue. It is the largest gland in the body, weighing nearly four pounds.

Bile.—Bile is a bitter, golden red, or sometimes greenish yellow, liquid made by the liver from the blood. About two and a half pints of bile are made daily.

The Bile Sac.—This is a sac of about the size and shape of a pear, and is attached to the under surface of the liver. It has a duct, the bile duct, which empties into the small intestine a few inches beyond the stomach. Part of the

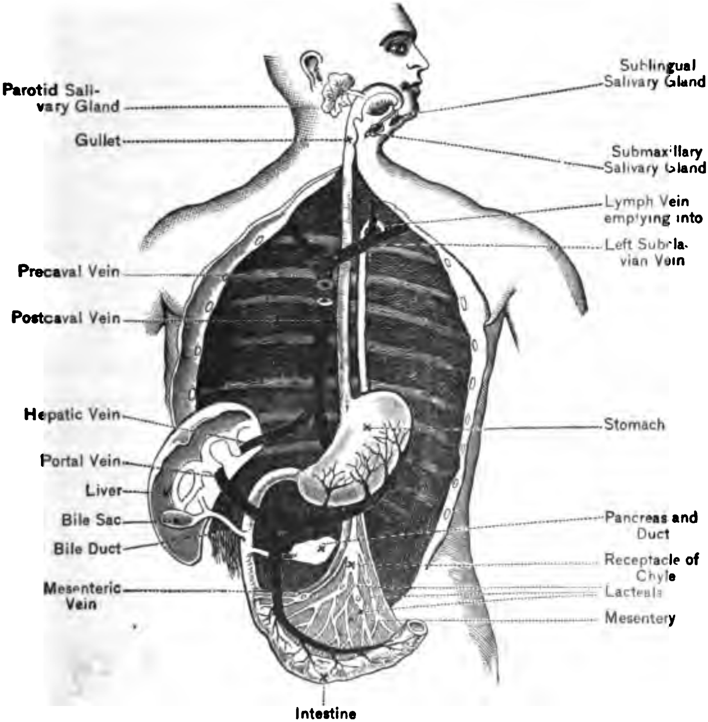


Fig. 74. The Organs which change Food into Blood.

bile is at once poured out into the intestine, but part, especially when we are not digesting, is stored in the bile sac, to be poured out during digestion.

Functions of Bile.—1. It aids in emulsifying the fats.
2. It aids in the absorption of fat.

3. The bile, to a certain extent, is waste matter; so the liver is an organ of excretion as well as an organ of secretion.

4. It is found that if, for any cause, the bile is prevented from entering the intestine, constipation follows, and the contents of the large intestine have a much more fetid odor than usual. The bile retards this putrefaction.

The Pancreas. — Just back of the stomach is another important gland, the pancreas. It is a pink organ, weighing three or four ounces and having the shape of a dog's tongue. It has a duct which empties into the small intestine at the same point where the bile enters, but it has no sac in which to store the liquid which it secretes. It takes from the blood certain materials and makes a liquid called pancreatic juice.

Pancreatic Juice. — This is a clear, sticky liquid, very much like saliva in appearance. Although the pancreas is a small organ, its work is very important. It gets a large blood supply and makes a large amount of pancreatic juice. The pancreas of calves is often eaten, being known by the name "sweetbread."

The Work of the Pancreatic Juice. — The pancreatic juice acts on all the principal classes of foodstuffs: —

1. A substance in it called amylopsin acts on starches, changing them to sugar even more actively than the ptyalin of the saliva.

2. Another substance in pancreatic juice is trypsin; like the pepsin of gastric juice, it changes proteids to peptones.

3. The pancreatic juice also emulsifies the fats. The fat is divided into exceedingly fine drops, each covered with a coating of albumen. An emulsion can be made artificially by shaking together water, oil, and white-of-egg.

The shaking breaks the oil into fine drops, which would soon gather again if no other substance were present; but the albumen forms a thin coating around each droplet, enabling it to remain distinct in the liquid.

The Intestinal Glands. — The mucous membrane of the small intestine has an immense number of tube-like glands. (See Fig. 78.) Their structure is much like that of the gastric glands shown in Fig. 73. Fig. 75 shows them as seen when cut across. These glands make a liquid called intestinal juice, which completes the work of the other digestive liquids.

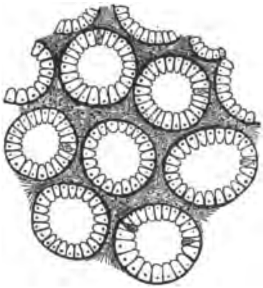


Fig. 75. Horizontal Section through the Mucous Membrane of the Intestine, showing Intestinal Glands in Transverse Section. (Highly magnified.)

Review of Digestive Liquids. — Saliva acts only on starch, gastric juice on proteids, bile on fats; but pancreatic juice acts on all three.

The Large Intestine. — This consists mainly of the *colon*, the final portion being called the rectum.

The Colon. — The small intestine joins the colon near the lower right side of the abdomen. Where the small intestine enters the colon there is a valve which keeps the material from coming back into the small intestine. The colon runs upward on the right side (ascending colon), crosses over to the left side (transverse colon), and descends on the left side (descending colon), and, after curving somewhat like a letter S, becomes straight again, this part being called the rectum. It is well to know the course of the lower bowel, as pressure may be so applied as to push the contents along in case the bowels become torpid. (Fig. 76.)

Review of the Digestive Tube. — The whole digestive tube may be briefly and roughly described as a muscular tube of varying diameter, lined by mucous membrane. The muscular coat pushes the contents along and mixes them with liquids; the mucous coat is beset with glands, making liquids, some of which merely soak the food, others act on it chemically, while mucus serves to make the surface slippery. It seems that these myriads of simple glands are not enough, so several large compound glands lie alongside the food tube and empty their secretions into it by ducts; these compound glands are the salivary glands, the pancreas, and the liver.

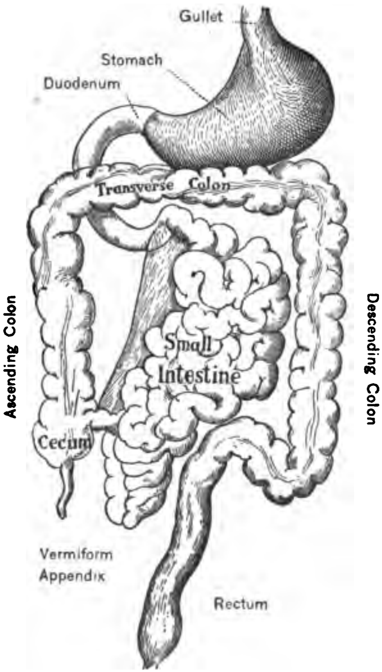


Fig. 76. The Stomach and Intestines.

Length of the Intestine. —The length of the small intestine is about twenty-five feet, and of the large intestine five or six feet. The large intestine is not a direct continuation of the small; that is, the small intestine opens at a right angle into the large near the beginning of the latter, so that there is a short blind end called the cecum (see Fig. 76). In some animals this is large and has considerable length, but in man it is very short. There is a closed

prolongation of the cecum, the vermiform appendix. This appendix is frequently the seat of serious or fatal inflammation, called appendicitis. This disease is not usually caused by the lodging of seeds in the cecum, as most people suppose; still it is better not to swallow such things.

A Simple Gland. — A gland is a structure which takes liquid from the blood and pours it out on some surface. In its simplest form a gland is a mere pit, or hole, such as the gastric glands, shown in Fig. 73. The blood capillaries give off lymph around the gland, and from this lymph the cells of the gland take their material. A sweat gland needs more length than a gastric gland, and the extra length is coiled up in a ball at the inner end. Many small glands are forked at their inner ends, thus increasing their surface.

Kinds of Glands. — Fig. 77 shows different forms of glands, from the simplest to the most complex. In the compound glands the lining of the duct, which is merely a passageway, is different from the rest of the gland. Glands that take waste matter from the blood are called excretory glands, such as sweat glands; they do not usually make much change in the material. Such glands as the gastric glands change the material that they pour out; the gastric juice is different from anything found in the blood. Such glands are called secretory glands. Sweat is an *excretion;* gastric juice is a *secretion.* Still, all glands are said to *secrete*, that is, to *separate* something from the blood. And gland action in general is called secretion. In structure, then, glands may be simple or compound. In function they may be excretory or secretory.

Control of Glands. — All glands are under the control of nerves. But this control is involuntary, and under the

management of the sympathetic nervous system. The mouth may "water" for some attractive food, or become dry through fear or anxiety. Hence we can see why a restful, contented condition of mind and body will be likely to favor the action of the many glands along the digestive tube; and, on the other hand, why anxiety or fretfulness are likely to hinder their action.

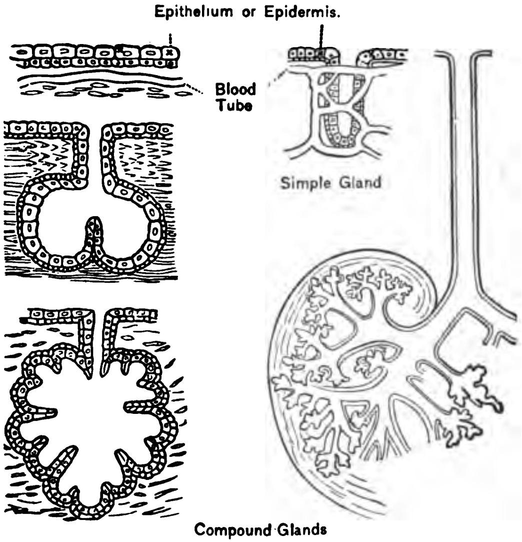


Fig. 77. Simple and Compound Glands.

Summary. — 1. The intestine has two coats, an outer, muscular, and an inner, mucous, coat.

2. The intestine consists of two parts, the small intestine and the large.

3. The liver is the largest gland in the body. It secretes bile, which is stored in the bile sac.

4. Bile aids in emulsifying and absorbing fats, and retards putrefaction. Bile is partly waste matter.

5. The pancreas is a small tongue-shaped organ back of the stomach. It secretes the pancreatic juice.

6. Pancreatic juice acts on proteids, fats, and starch.

7. In the walls of the intestine are many small intestinal glands. Their secretion helps complete the process of digestion.

8. The main part of the large intestine is the colon. It has three parts, ascending, transverse, and descending. The last part of the intestine is the rectum.

9. The small intestine is twenty-five feet long, the large, five or six.

10. A gland is a hollow structure that secretes a liquid from the blood.

11. Glands are simple, like an intestinal gland, or complex, like the pancreas.

12. Glands are excretory, such as the sweat glands, or secretory, such as the gastric glands.

Questions. — 1. Why is there such a difference in the lengths of intestine in the cat and the cow?

2. What is biliousness?

3. Why is the pancreas sometimes called the "abdominal salivary gland"?

4. Why does digestion proceed more slowly in the intestine than in the stomach?

5. In what direction should the abdomen be rubbed to assist a movement of the bowels?

CHAPTER XVIII.

ABSORPTION.

Absorption a Living Process. — The layer of cells which forms the inner surface of the mucous membrane is called epithelium. These cells are moist, soft, and thin-walled. They take up the digested foods, now in liquid form, and pass them on to the lymph and so into the blood capillaries that are thickly distributed just beneath the surface.

Absorption from the Mouth. — Sugar, and some other substances, may be absorbed by the mouth as soon as it is dissolved. But very little material is thus absorbed.

Absorption from the Stomach. — Some parts of the food that are already digested, or such matters as are soluble, *e.g.* water containing sugar, peptone, salts, etc., may be absorbed immediately through the walls of the stomach into the blood capillaries. Recent experiments show, however, that the amount of absorption from the stomach is much less than was formerly supposed; water, for instance, "when taken alone, is practically not absorbed at all in the stomach. As soon as water is introduced into the stomach it begins to pass out into the intestine, being forced out in a series of spurts by the contractions of the stomach."

Absorption from the Small Intestine. — Most of the digested food is absorbed in the small intestine.

Increased Surface for Absorption. — The mucous membrane of the small intestine is thrown into ridges, but, unlike those of the stomach, they run crosswise. Again,

while the folds in the lining of the stomach are temporary, these are permanent. They increase the surface of the lining and retard the passage of the food material, and so aid the process of digestion and of absorption.

Villuses. — To increase, still further, the surface for absorption, the mucous membrane of the small intestine is thickly covered with little cylindrical projections, like the "pile" on velvet. Each of these projections is a villus.

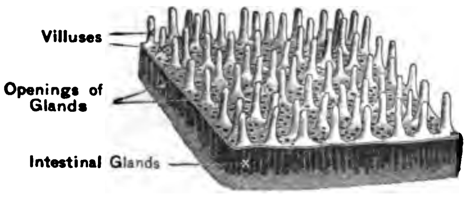


Fig. 78. Mucous Membrane of Small Intestine, showing Intestinal Glands and Villuses, greatly Magnified.

Structure of a Villus. — A villus is about a thirtieth of an inch long. It is made up of four parts: (1) on the outside a layer of soft, moist, thin-walled cells; (2) plain muscle fibers, running lengthwise; (3) a network of blood

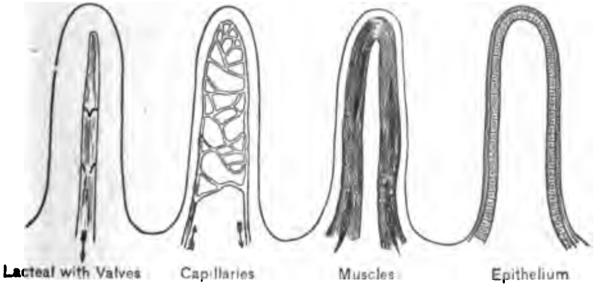


Fig. 79. Four Parts of a Vilius, greatly Magnified.

capillaries; and (4), near the center, lymph capillaries, called lacteals. Fig. 79 shows these four parts separate, while Fig. 80 shows them combined, as they are in the complete villus.

Absorption by the Villuses. — The digested food is in liquid form and surrounds the villuses. The three main substances to be absorbed are peptones, sugar, and fat. The outer cells of each villus absorb these and pass them inward. The peptones and sugars are taken into the blood capillaries, while the fats enter the lacteals.

Muscular Action of the Villuses. — In each villus there are plain muscle fibers. When these shorten they squeeze the chyle, that has already been absorbed, into the lymph tubes of the wall of the intestines, and on into the main

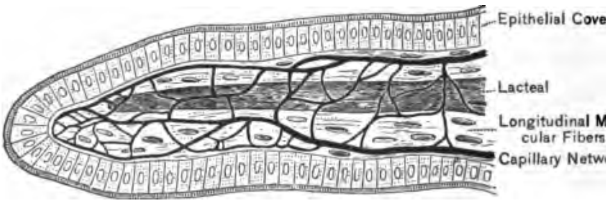


Fig. 80. A Complete Villus, very greatly Magnified.

lymph duct. The chyle cannot return to the lacteal when the muscles relax, on account of the valves, similar to those of the veins, in the lacteal at the base of the villus. Then, when the muscles relax, the lacteal is empty, and ready to absorb more of the emulsified fat that we call chyle. This action also helps the flow in the blood capillaries.

The Lacteals and Lymphatics. — While the main work of the lymphatics, as we have seen, is the carrying of lymph from the tissues of the body to empty into the veins of the neck, the lymphatics of the intestines have another important function. They absorb and carry the fatty portions of the digested food into the general circulation. During most of the time the thoracic duct and

the lymphatics of the intestines would hardly be noticed because they are filled with the clear lymph. But after

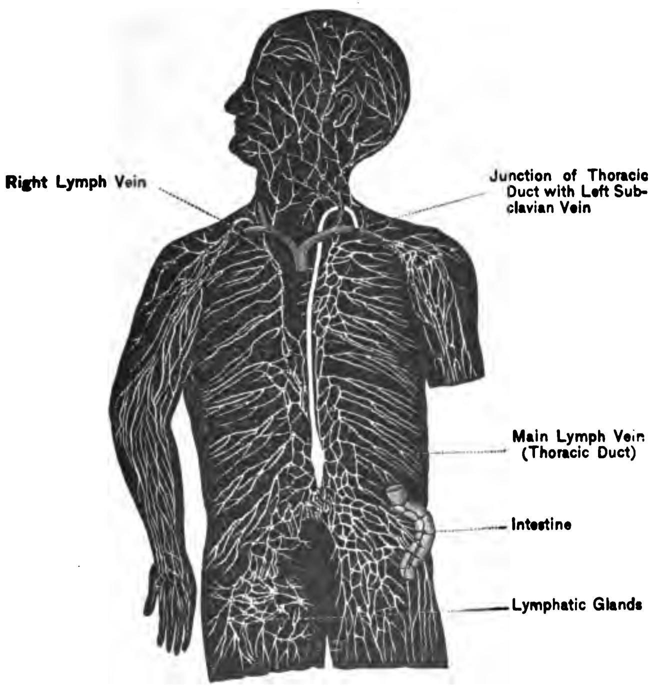


Fig. 81. Lymph Veins (Lymphatics).

absorption of fatty matter they are filled with a white liquid, called chyle, and are easily seen. (See Fig. 81.)

The Portal Circulation.—All the veins coming from the stomach and intestines unite to form a large vein that goes to the liver; this is the portal vein. When the portal vein enters the liver it does what veins do not do elsewhere in the body,—it divides into smaller branches. This division

and subdivision goes on till the portal vein forms capillaries branching all through the liver.

The blood from these capillaries collects again in veins, which unite in one vein, the hepatic vein, which carries the blood into the postcaval vein just under the diaphragm.

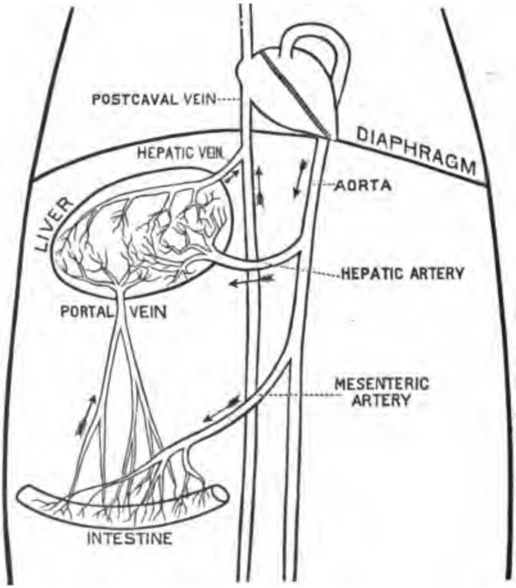


Fig. 82. Diagram of Portal Circulation.

Going back again to the beginnings of the portal vein, it is clear that it starts from the capillaries of the stomach and intestines. And these capillaries, as we have just seen, absorb the peptones and sugars. The sugars and peptones, therefore, go directly to the liver after being absorbed.

Double Blood Supply to the Liver.—The liver also receives blood from the hepatic artery, a branch of the aorta.

Thus the liver gets blood from two sources, the portal vein and the hepatic artery, but is drained by one vein, the hepatic vein.

Work of the Liver.—We have seen that the liver makes bile. The liver also makes another substance out of the blood that passes through it. This is glycogen, or "animal starch." It is also called "liver sugar," as it gives to liver

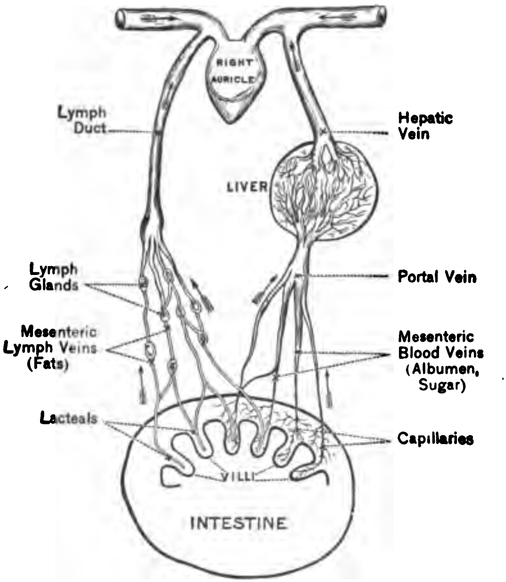


Fig. 83. Plan of Absorption.

a sweetish taste. Glycogen is given back to the blood and carried away by the hepatic vein to the body, where it serves as food to the tissues.

Routes of Different Foods after Absorption.—There are, then, two routes taken by the food after absorption. The peptones and sugars go to the liver through the portal

vein, while the fats are carried by the main lymph duct, or thoracic duct. These two streams unite before reaching the heart. The fats pass around the liver, instead of through it as do the peptones and sugars.

PARTS OF DIGESTIVE TUBE.	MECHANICAL PROCESSES.	GLANDS.	LIQUIDS.	CHEMICAL CHANGE.	ABSORPTION.	
					MATERIAL	BY
MOUTH.	Cutting and Grinding.	Salivary.	Saliva.	Starch to Sugar.		
PHARYNX.	Raising Soft Palate. Depressing Epiglottis.					
GULLET.	Food carried to Stomach.	Mucous.	Mucus.			
STOMACH.	Churning and Mixing.	Gastric.	Gastric Juice.	Proteid to Peptone.	Water. Salts. Sugars. Peptones.	Blood Capillaries.
SMALL INTESTINE.	Mixing and Moving Food.	Liver. Pancreas. Intestinal.	Bile. Pancreatic Juice. Intestinal Juice.	Starch to Sugar. Proteid to Peptone. Fats Emulsified. Decomposed.	Water. Salts. Sugar. Peptone. Fats.	Blood Capillaries. Lacteals.
LARGE INTESTINE.	Food Forced on.	Mucous.	Mucus.		Water.	

Fig. 84. Outline of Digestion and Absorption.

Amount of Liquid Absorbed.—It is estimated that there is poured into the digestive tube daily one quart of saliva, four or five quarts of gastric juice, one quart of bile, and about a quart of pancreatic juice. If the food and drink amounts to two quarts, there must be more than two gallons of liquid absorbed from the digestive tube each day.

The Work of the Large Intestine. — Most of the absorption is accomplished in the small intestine; but as the food passes on into the large intestine the work of digestion and of absorption is carried somewhat farther. If the residue be not soon expelled, there may be absorption of some of the results of putrefactive changes, and a sort of general poisoning of the whole body. Hence the great importance of regularly and thoroughly emptying the lower bowel. The matter thus expelled is largely made up of indigestible material, with some real waste substances.

Taking up again our comparison of the body and a stove, we see that the feces are not true waste products, but are rather clinkers, or material that has not been burned or oxidized in the body. The real wastes of the body are the carbon dioxid, urea, water, etc., that are produced by the oxidation of the tissues, and are mostly thrown off by the lungs, kidneys, and skin.

Summary. — 1. The cells lining the digestive tube take up the digested food, now in liquid form, and pass it into the lymph.

2. There is some absorption, from the stomach, of sugar and peptone. Most of the absorption is from the small intestine.

3. The hair-like villuses greatly increase the absorbing surface.

4. A villus has four parts, the outer layer of cells, plain muscle fibers running lengthwise, blood capillaries, and lacteals.

5. The outer cells of the villus take up the liquefied food.

6. Sugar and proteids enter the blood capillaries; fats enter the lacteal capillaries.

7. The muscles of the villus pump the liquids along and aid absorption.

8. The lacteals are part of the lymph system of the body. They absorb and carry fats.

9. The veins from the stomach and intestine join to form the portal vein which enters the liver. Here it breaks up into capillaries.

10. The liver has two supplies of blood, from the portal vein and the hepatic artery. It is drained by one vein, the hepatic vein.

11. The liver makes bile and glycogen.

12. Sugars and proteids go through the liver; fats pass around the liver through the main lymph vein, or thoracic vein.

13. There are over two gallons of liquids absorbed daily.

Questions. — 1. Why is it best to begin a hearty meal with soup?

2. Why should the liver receive so much blood?

3. What is the meaning of "biliousness"?

4. What is the advantage of a "fruit diet"?

5. Why does active exercise tend to keep the bowels open?

CHAPTER XIX.

HYGIENE OF DIGESTION.—NUTRITION.

Digestion and Circulation. — During digestion there must be a large supply of blood in the digestive organs. It is needed both to supply the material for the glands to make the digestive liquids and also to absorb and bring away the newly digested food. Therefore, during digestion there must be less blood in other parts of the body.

Digestion and Muscular Work. — If one exercises actively immediately after eating, the process of digestion will be interfered with, because the blood will be drawn away from the digestive organs to the muscles. It is well to rest for a short time after eating a full meal.

Digestion and Study. — For the same reason it is better not to begin hard study immediately after a full meal. The blood needed for the work of digestion will be called to the brain, and digestion will suffer.

Solid Foods digest Slowly. — If a very hungry person begins his dinner with solid food, he is likely to eat too fast. Hunger is a demand of the system for food. It takes some time for solid food to go through all the processes of digestion, and be absorbed into the system and satisfy hunger.

Value of Soup. — But if the meal begins with soup, which is readily absorbed, the demand of the system will begin to be met, and there will not be the same tendency to rapid

eating. Further, a warm soup stimulates the blood flow in the mucous membrane, and thus prepares for more thorough digestion.

Desserts. — Dessert and sweetmeats, following a meal, are often helpful by further stimulating the secretion of the glands. Nuts, which are not very digestible, are beneficial if eaten sparingly. The agreeable taste stimulates the salivary glands, and the saliva stimulates the gastric glands to increased activity. The danger in taking dessert is that the pleasing taste tempts us to continue eating after we have had enough. Pie is usually hard to digest.

The Bad Effects of Imperfect Mastication. — If we swallow food before it is thoroughly ground and mixed with the saliva, the stomach and other parts of the digestive organs will require much more time to reduce the food to a liquid form. Further, when eating hastily, we are very apt to eat too much. Thus we may give the stomach a double amount of material to handle, and the material may not be half so well prepared as it should be. Of course the organs suffer and break down if this treatment is continued.

Effect of Repose on Digestion. — Not only mastication, but the whole process of digestion, goes on better when the body and mind are at rest and in a peaceful condition, as all the glands are under the control of the nervous system, and are greatly influenced by the condition of the body. During a meal, and for a short time before and after, all thoughts of one's occupation, and especially all anxiety, should be dismissed from the mind. For those whose digestion is not strong, it is desirable to rest after each meal.

Conversation at Meals. — During a meal there should be conversation on topics of general interest. Talking at the

table also makes us more deliberate in eating. "Chatted food is half digested."

Time of Eating. — The American custom of three meals a day seems well adapted to the needs of our people. The best time for the chief meal is near the middle of the day, as is the custom in the country; for the bodily powers are higher than later in the day. But for city people, and others who are very busy in the middle of the day, it is undoubtedly better to take the chief meal after the rush of the day's work is over, when there is time for a deliberate meal and when the mind is free from business cares. In many homes this is the only time when the whole family can leisurely meet at the table.

Eating between Meals. — The stomach should have time to rest and prepare for the work of digesting another meal. Many find two meals a day sufficient. There are some persons, however, for whom it would be better to have more meals, with less food at a time. Meals should be regular.

Amount of Food Needed. — This varies greatly with the individual, age, the kind and amount of labor, etc., so that no very helpful rule can be given. Each person must find by experience what is best for himself. It is the opinion of many leading physicians that the majority of mankind eat too much.

Intemperance in Eating. — "I have come to the conclusion that more than half of the disease which embitters the middle and latter part of life is due to avoidable errors of diet; and that more mischief, in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man from erroneous habits of eating than from the habitual

use of alcoholic drink, considerable as I know that evil to be." — *Thompson.*

Self-denial in Eating. — It is a good old saying, "We never repent having eaten too little." Nearly every one has regretted having eaten too much. It is better to stop before one has eaten quite as much as he would like, especially when taking highly-seasoned or sweetened food.

Fat as a Tissue. — As a tissue fat serves as a stored-up food. A fat person can endure starvation longer, other things being equal, than a thin person. A layer of fat under the skin serves also as a heat saver.

Hibernation. — Hibernating animals are fat when they enter upon their winter sleep, but are lean when they come out in the spring. Remaining inactive, they have produced very little energy, their only motions being a slow and feeble breathing and heart-beat. They have consumed the fat, using it mainly in maintaining the necessary heat. In short, they have burned their fat to keep them warm.

Importance of Renewal of Blood and Lymph. — The lymph surrounds the individual cells which make up the tissues of the body. Every cell lives an independent life, to a certain extent, taking its nourishment directly from the lymph around it. The importance of an abundant supply of good lymph is apparent. The supply and renewal of the lymph depends on the blood.

Effect of Digestion on Blood and Lymph. — If digestion is not good, or if there is not enough good food, good blood cannot be made, and the lymph will not be good. The cells are more or less starved, or poisoned if wastes are not properly removed, and the general tone of the body will soon be lowered; for the health of the body as a whole depends on the average condition of the cells composing

the body, just as the condition of any community depends on the average condition of the individuals of that community.

Assimilation. — The formation of tissue from the materials brought by the blood is assimilation. It is the last step in building up the tissues.

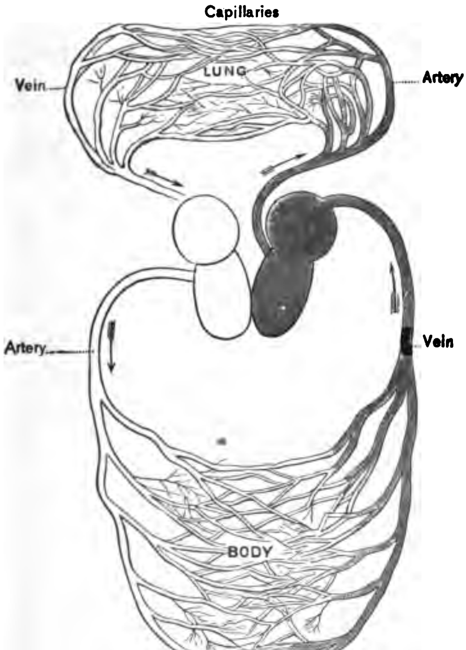


Fig. 85. Diagram of the Heart and Blood Tubes (Back View).

Blood a Mixture of Good and Bad. — In the blood streams are combined the good and the bad. The newly digested food is received into a current of impure blood in the post-

caval vein. The blood from the kidneys, probably the purest blood in the body, joins the same impure stream. From the aorta, red blood, usually called pure, — the same

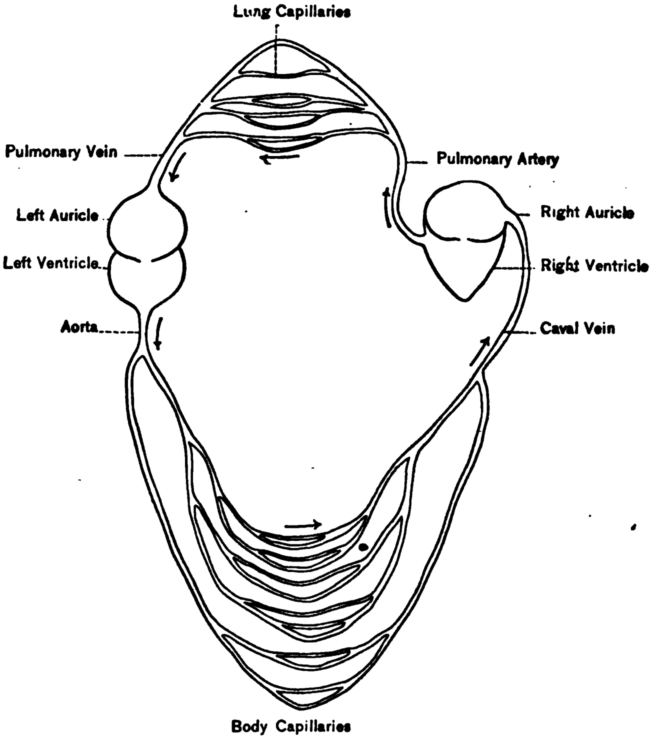


Fig. 86. Plan of Circulation, representing the Right and Left Halves of the Heart separated, showing that the Blood makes but One Circuit.

kind that goes to the brain, — is sent to the kidneys and to the skin to be purified. Yet, as this mixed blood flows through each organ, that organ, so long as it is in health, takes from it only what it should take.

Action of Diseased Kidneys. — The kidney takes, during health, only the waste matters, leaving the valuable nourishing material. But, in disease, the kidneys may take out some of the most valuable nourishing material. Suppose that in a mill, a workman, whose business is to shovel out wastes, becomes crazy, and shovels wheat or flour out of the mill into the stream below. The diseased kidney may be said to have become crazy, and in the disease called "diabetes" throws out sugar, and in "albuminuria" excretes albumen.

Blood Streams like Water Pipes and Sewer Combined. — It is as though the water supply of a city house was taken from the sewer; each organ needing a supply of building material acts like a filter, taking from the blood what it needs, paying no attention to the impurities present, and the organs of excretion select the impurities, allowing the useful substances to pass on to the places where they are needed. Figs. 85, 86, and 87 show what the blood stream gives to each of the organs of the body and what it takes from them to throw out as waste matter.

How the Body Changes. — The body is continually changing, new material from the digested food taking the place of the worn-out tissues. It is a common saying that the body changes once in seven years. But while the more active tissues, such as muscle, must change many times in a year, we know that the teeth do not grow after they are once formed.

The Body like an Eddy. — The changes in the body have been compared to an eddy in a stream. The form of the eddy remains the same, while particles of water are entering on one side and leaving on the other. In a short time

all the particles are changed. But in the body the more permanent parts change slowly.

Nutrition. — Nutrition includes all the changes that take place in the body from the reception of food to the excretion of the waste matter. It includes digestion, absorption, circulation, assimilation, respiration (oxidation), and excretion. The first four of these processes are stages in *building up* the tissues; the last two are process of *tearing down.*

We cannot destroy Matter. — When a stick of wood is burned it is no longer wood. But the matter is not destroyed. It could all be obtained again from the smoke and ashes. So, in the continual wasting away of our bodies, there is no real loss of matter. Our weight is reduced, but the wastes are still part of the earth or the air, and are of use in the world. We are as unable to destroy matter as we are to create it.

The Ceaseless Round of Matter. — A particle of carbon in the carbon dioxid of the expired breath may be taken in by a blade of grass. A cow eats the grass, and we may before long take the very same particle of carbon in the milk or the flesh of the cow. Or the particle of carbon may become part of a grain of wheat, and be made into flour and be eaten as bread and be a part of the body once more. Thus, there is a ceaseless round of matter into and out of our bodies. No one has a monopoly of any portion of matter; it is now ours, now some one else's.

We cannot create Force. — We get our energy from the food we eat, just as an engine gets its energy from fuel. This is saying nothing against the superiority of the human body and is not in the least degrading. We are living, growing, self-directing, and self-maintaining ma-

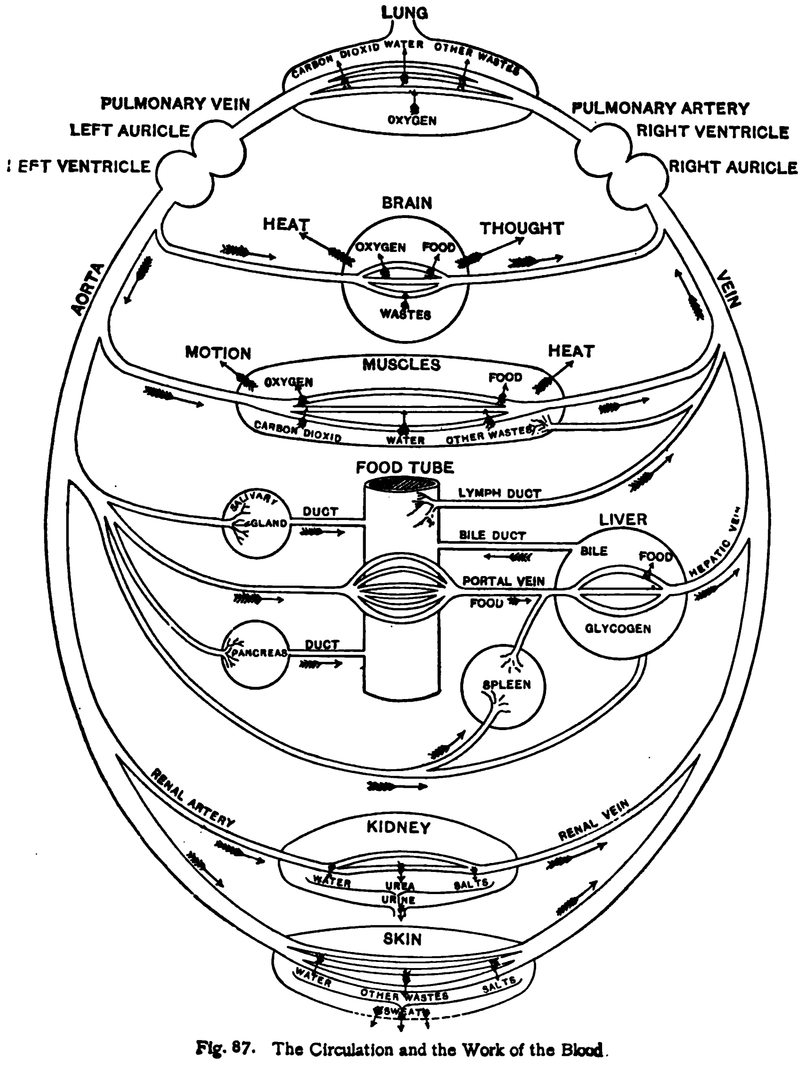


Fig. 87. The Circulation and the Work of the Blood.

chines. Still, starvation soon puts an end to our ability to produce energy of any kind.

How we depend on Plants. — The larger part of our food is vegetable. And the animal foods, such as meat, milk, cheese, butter, eggs, etc., were made by the animals from vegetable matter. We are, therefore, directly or indirectly, dependent on plants for all our food. On the other hand, plants use as their food considerable of the waste matter thrown off by animals.

Summary. — 1. During digestion a large supply of blood is required in the digestive organs.

2. Muscular work, immediately after eating, interferes with digestion by calling the blood away to the muscles.

3. Hard study, right after a hearty meal, hinders digestion in the same way.

4. Soup is a good beginning of a hearty meal, as it is more readily absorbed than solid food.

5. Desserts, in moderate quantity, are useful in stimulating the glands which supply the digestive liquids.

6. Hot drink at meals aids weak digestion.

7. Imperfect mastication leads to eating too much, and throws too much work upon the other organs of digestion.

8. A calm condition of the nervous system favors digestion.

9. Conversation on cheerful topics is favorable to digestion.

10. Three meals a day are best for most persons.

11. For persons hurried in the middle of the day it is often better to take the chief meal at the close of the day's work.

12. Meals should be regular, and one should not eat between meals.

13. There is much intemperance in eating.

14. Fat, as tissue, is stored food.

15. The cells depend on the lymph for their nourishment, and the lymph is supplied by the digested food.

16. The blood is a mixture of good and bad material; each organ, in health, selects from the blood what it needs, the tissues taking nourishment, and the organs of excretion removing the waste matters.

17. Diseased kidneys may remove valuable nourishing materials from the blood.

18. The body keeps changing, taking new matter to replace worn-out tissue.

19. Nutrition includes digestion, absorption, circulation, respiration, assimilation, oxidation, and excretion.

20. We cannot destroy matter. Our waste products become part of earth or air.

21. We cannot create force. We get our energy from food as an engine gets its energy from fuel.

22. We depend on plants for our food.

Questions. — 1. Should a person who has studied hard try to do hard muscular work the same day?

2. What are the advantages of a "course" dinner?

3. Which is more wholesome, dry toast or soaked toast? Why?

4. Why do we give a horse exercise and keep fattening stock quiet?

5. Are fat people large eaters? Are thin people light eaters?

6. Do sweat glands ever excrete valuable material?

7. In Fig. 87 find what the blood gives to each organ and what it takes from each.

8. Classify the organs represented in Fig. 87.

9. Name the organs that change most rapidly.

10. Name the organs that change most slowly.

11. What is the source from which plants get their energy?

12. Is matter defiled in passing from one body to another?

CHAPTER XX.

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EXERCISE AND BATHING.

How Exercise is Beneficial. — Exercise stimulates the cells to activity and renews the lymph around the cells both by quickening the blood flow and by pressure on the lymph tubes. The glands of excretion are set to work more actively, and the more rapid blood stream brings away the material to be thrown out.

Exercise for General Health. — Exercise is not merely for the muscles. It quickens the action of the whole body by increasing cell activity. It helps clean out the system and clear the brain as well. It is not so much strength as health that we need. The ability to do our daily work, to do it with comfort and without any feeling of strained effort, is what we need.

Exercise prolongs Life. — Many men would live longer, feel better, and do greater good in the world, if they took regular and systematic exercise. It is a shortsighted policy to say, "I cannot afford the time." Not to take time for exercise is to mortgage one's future. "He who does not take time for exercise will have to take time for illness." The latter half of every person's life ought in many respects to be by far the most productive of good. But many cut off this half, or render it less useful through breaking down in health as a result of violating the laws of health.

Nature's Rewards and Punishments. — Nature never fails to punish every violation of her laws. Her reward for obedience is health and the delight that accompanies it.

Useful Exercise. — The man, woman, boy, or girl who has regular work that calls for muscular activity is to be congratulated. Duty obliges them to take regular exercise. The boy who has "chores" to do is to be envied rather than pitied.

Choice of Exercise. — But many persons are so situated that they have no work to do. They must choose some exercise that is not for a directly useful purpose. In selecting exercise one should choose (1) that which is enjoyable, for exhilarating exercise is much more beneficial than that which is taken as a necessity; (2) exercise should be in the open air whenever possible.

Forms of Exercise. — There is a great variety of forms of exercise from which each person can select according to his age, strength, etc. For active youths there are running, jumping, wrestling, boxing, fencing, hare and hounds, putting the shot, putting the hammer, vaulting, baseball, and football. In their season come boating and swimming, skating and coasting. Suitable for both boys and girls are archery, basket ball, bicycling, croquet, golf, horseback riding, tennis, and last, but not least, walking. The main trouble with walking is that it is likely to be taken from a sense of duty and becomes mechanical. The good feature of most games is that there is active competition, which makes them so enjoyable that one entirely forgets his work for the time. He is, therefore, in better condition to return to his work.

Exercise in One's Room. — In one's room he can use dumb-bells or Indian clubs to good advantage. There are

also various forms of "home exercisers," such as pulley weights, rubber bands, etc., which are valuable. After exercise should come a sponge bath.

Games of School Children. — Most of the games of school children are excellent kinds of exercise. Cases have been reported of injury from excessive skipping the rope; but in moderate degree it is a good exercise. Tag, snowballing, racing, the various games of ball, jumping, hopping, and other games may be played on the school grounds.

Tennis. — Tennis is a fine game and suitable for girls as well as boys. It has the great advantage over baseball that it does not require a large ground. Two can make up a game, and a little time can be better used than with the games requiring more players. The exercise, too, is more evenly distributed. There is no long waiting, as in some games, but a constant interchange of play, active but not severe, with almost no danger of injury.

Baseball and Football. — For those who can pursue the more vigorous games of baseball and football they are admirable. All these games calling for great activity and strength develop manly qualities in boys, and do much to make them active, fearless men, men who in time of danger have not only strength and endurance, but well-trained muscles, cool heads, and brave hearts; men who know what to do and how to do it in an accident, as at fires, upsetting of boats, etc. A few strong, cool-headed men, by their presence of mind, often stop a panic and save many lives when there is an alarm of fire, which often proves false. The Duke of Wellington said that it was on the football fields of Eton and Rugby that the battle of Waterloo was won.

Boxing. — Boxing is a splendid exercise. It calls into play nearly every muscle of the body. Boxing makes one quick on his feet, trains to quick movements of the arms, trains the eye, keeps the body in an erect position, and especially develops the muscles of the legs and back. Boxing brings out the chest and shoulders. It develops the "wind," and keeps one in constant action. It teaches control of the temper more than almost any form of exercise. It develops a degree of self-reliance that is worth much. Like tennis, boxing calls for little appa-

ratus, little space, and only two persons. In many places where ordinary gymnasium work is out of the question, boxing is available. It is indeed a "manly art," and the doctrine taught in *Tom Brown's School Days at Rugby* is as wholesome as can be given to boys to make them strong and active, to give them physical and moral health.

Bicycling. — This is an excellent exercise, as it is in the open air and exhilarating. There is danger of over-exertion, and it is bad for one to yield to the temptation to make long runs. There is danger of overtaxing the heart. The handle bar should be adjusted to allow a fairly upright position. The saddle should be such as to sustain the weight properly.

"Taking Cold." — So long as one is actively exercising, he is not likely to take cold. But if one rests in a cool place, especially when he is warm, he is likely to take cold. The application of cold to the skin causes the arteries (through reflex action) to become smaller. Thus when resting in a cool place the skin becomes pale and cold. During a "cold" there is fever. The regulation of the heat by the skin is interfered with. Waste matter is not given off by the skin as it should be. At the same time it is often noticeable that the urine is more abundant than usual. A cold is often associated with constipation and inactivity of the liver, indicating a clogged condition of the system. As a cold may lead to fatal lung disease, so it may be the beginning of disease of the kidneys that may, in the end, bring fatal results.

Bathing. — One purpose of bathing is to cleanse the skin. For this purpose warm water is best, and it is desirable to use soap, especially on those parts which are especially exposed to contamination, such as the hands, the feet, the armpits, and groins. The feet should be bathed every night.

Cold Baths. — Another important function of bathing is to strengthen the system. For this purpose cold bathing is better, but this should not be too long continued, and must be followed by a brisk friction to give the skin a ruddy glow. For this kind of bath a tub is not necessary, and hardly desirable. The water may be quickly applied by means of a sponge, or bath mits made of Turkish toweling, and the body thoroughly rubbed with a coarse towel. The whole process should be completed very quickly, especially if the room is not warm. At the beginning of a bath, cold water should be applied to the head and face.

Time for Bathing. — For those who do not take a great deal of vigorous exercise, which keeps the skin active, bathing is especially valuable. The use of warm water for cleansing seems best adapted to the time of going to bed. But the best time for the cool bath is on getting up in the morning.

Warm Baths vs. Cold Baths. — Prolonged warm baths are weakening, and probably increase a tendency to take cold, whereas cold bathing is one of the very best means of fortifying against cold, and especially against the tendency to take cold on slight exposure. For most persons a cool sponge bath, on rising, will act as a most excellent tonic; but if it seems to produce neuralgia, it should be used with caution.

Exercise of Arterial Muscles. — We have learned that the blood supply to any organ is regulated by the action of the plain muscle fibers in the walls of the small arteries. Now, when we are subject to changes in temperature these muscles get exercise, and one writer has well called the cold bath the *gymnastics of the plain muscle fibers,*

and we can understand how the system can be trained to adjust itself to cold, and enabled to avoid "taking cold."

Habit of Cold Bathing acquired Gradually. — There are undoubtedly many persons who do not profit by cold bathing, but probably many of these would soon adapt themselves to it by beginning with tepid water and gradually using cooler. To bath slowly in a cold room is not safe. The great secret of the benefit that may be expected from a cold bath is to be very brisk, the whole process occupying only a few minutes. Many are opposed to cold sponge bathing, and condemn it without giving it a fair trial.

Summary. — 1. Exercise stimulates the activity of all the organs, by promoting cell activity and assisting excretion.

2. Exercise should be in the open air as much as possible.

3. Exercise is more beneficial when it exhilarates.

4. Exercise should be taken regularly.

5. Warm baths are best for cleansing, and should be taken at bedtime.

6. Cold baths stimulate the circulation of blood in the skin, and serve as a tonic to the whole system. Just after rising is a good time for the cold bath.

7. The cold bath fortifies against taking cold.

Questions. — 1. Should exercise be carried to the point of fatigue?

2. How can one avoid taking cold after exercise?

3. Do girls need exercise as much as boys?

4. What is the condition of the body during a "cold"?

5. How may a cold be caused?

6. How may a cold be cured?

7. How may a cold be prevented?

8. Why do some persons take cold more readily than others?

9. Why does the same person take cold more readily at one time than at another?

10. How often should a person bathe?

11. What hour is best for sea bathing? Why?

CHAPTER XXI.

THE BRAIN.

The Coverings of the Brain. — There are two coats of the brain, the *dura mater*, a tough membrane, adhering to the inside of the skull; and the *pia mater*, next to the brain, a much thinner membrane, traversed by blood tubes, and dipping down into the grooves between the convolutions of the cerebrum.

The Parts of the Brain. — The parts of the brain are the *cerebrum*, the *cerebellum*, and the *spinal bulb*.

The Cerebrum. — The cerebrum consists of two lateral hemispheres, separated by a deep groove in the middle line. The surface of the cerebrum is in irregular ridges, the convolutions. The outside of the brain consists of gray matter. The inner part of the brain is white, and the two halves are connected by a broad band which consists of many white fibers.

The Cerebellum. — Back of, and below the cerebrum is the cerebellum. It is much smaller than the cerebrum, and has fine transverse ridges and grooves in place of the convolutions of the cerebrum. It is also of a deeper color, a reddish gray.

The Spinal Bulb. — The enlarged beginning of the spinal cord is the spinal bulb. It is white, like the rest of the cord.

The Cranial Nerves and their Functions. — 1. The *olfactory lobes* extend forward under the fore part of the cerebral hemispheres. They are the nerves of smell.

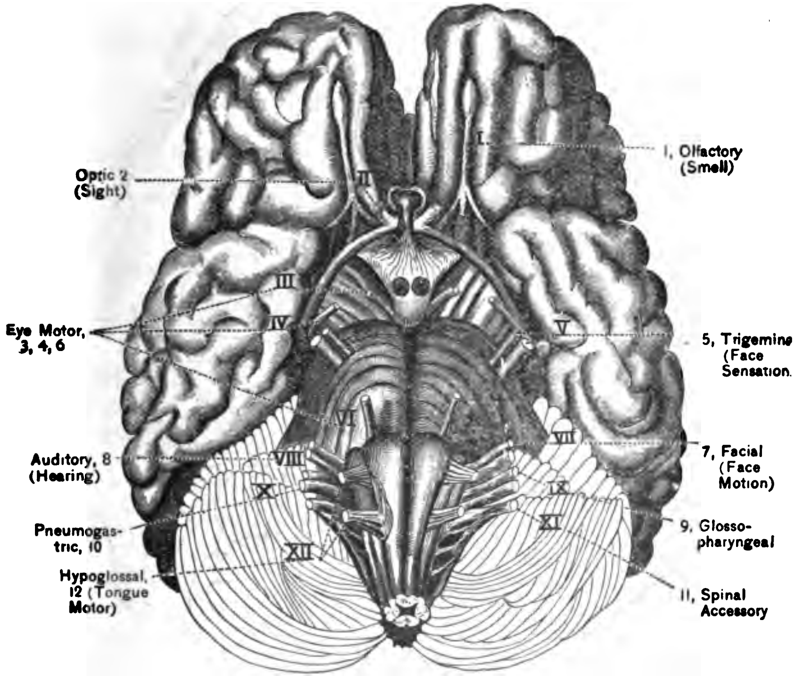


Fig. 88. The Base of the Brain, showing the Origin of the Cranial Nerves.

2. The *optic nerves*, or nerves of sight, join each other before reaching the brain.

3. The third pair of cranial nerves controls part of the muscles of the eyeballs.

4. The fourth pair also controls eye muscles.

5. Back of these is the larger fifth pair, the *trigeminal.* This pair supplies part of the face, and sends branches to

the teeth. It is the nerve affected in neuralgia of the face. It is the nerve of sensation for most of the head and face.

6. The sixth pair controls eye muscles.

7. The seventh pair are larger, and are farther back and outward. These are the *facial nerves*, and control the muscles of the face and the facial expression.

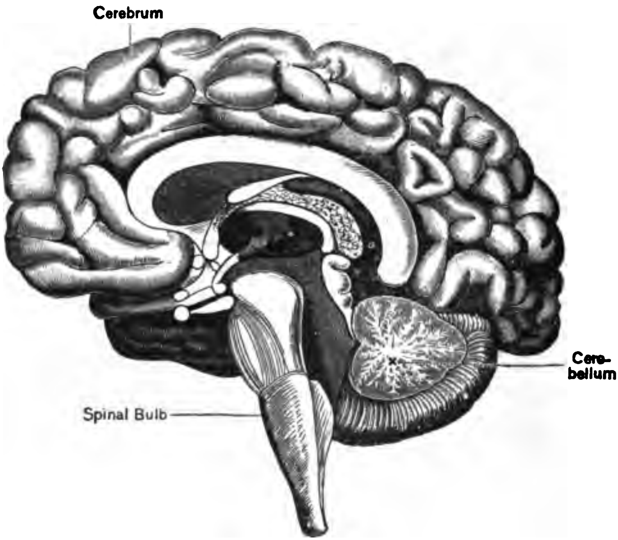


Fig. 89. Vertical Section of Brain.

8. The eighth, or *auditory nerves*, are the nerves of hearing.

9. The ninth pair arise on the sides of the spinal bulb. They supply the back of the tongue and the pharynx, and are called the *glosso-pharyngeal* nerves. They give the sense of taste from the base of the tongue.

10. The tenth pair, or *vagus nerves*, pass down out of the brain cavity, give off branches to the pharynx and

larynx, and are distributed to the heart, lungs, and stomach.

11. The eleventh pair arise in part from the spinal cord outside of the cranial cavity, enter the skull, and pass out again to supply certain muscles of the neck and shoulders.

12. The last pair of cranial nerves, the twelfth, supplies the muscles of the tongue, and are called the *hypoglossal nerves*.

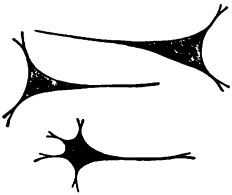


Fig. 90. — Nerve Cells of the Gray Matter of the Brain.

Gray and White Matter of the Brain. — The gray matter of the brain is composed of cells similar to those of the spinal cord, while the white matter of the inner part is composed of white fibers like those of the outer part of the spinal cord, or of the nerves.

Ganglions of the Brain. — There are several masses of gray matter in the interior of the brain. These are the ganglions of the brain. The white fibers inside the brain connect the gray matter of the convolutions and these ganglions with all parts of the body through the spinal cord.

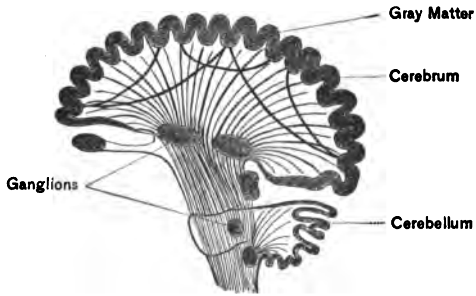


Fig. 91. Diagram of the Brain, showing the Spinal Cord, Ganglions, and Course of the Fibers.

Functions of the Cerebrum. — The gray matter of the outside of the brain is the central organ of intelligent sensation and motion. The functions of *volition*, or *willing*, of *consciousness*, of *intelligence*, seem to reside in, or rather to depend upon the activities of, the cells of the gray matter of the convolutions of the cerebrum.

The Center of Sensations itself Insensible.—All sensation seems to be in the gray matter of the convolutions of the cerebrum, and yet it is itself insensible; it may be cut and cause no sensation. But when the nerve impulses from the various parts of the body reach the gray matter of the cerebrum they rouse the cells here to an activity that gives us what we call sensation. It is never a sensation until it reaches this part and is properly interpreted.

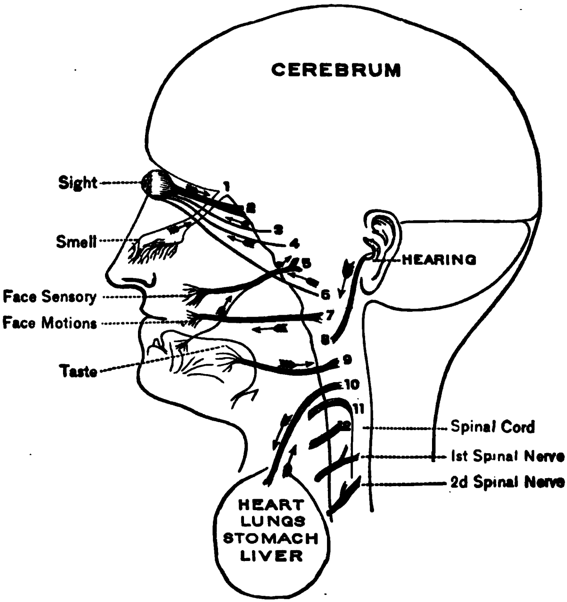


Fig. 92. The Cranial Nerves and Sense Organs.

Crossed Control of the Body.—While each hemisphere mainly controls the muscles of the opposite half of the body, it also, in part, has control of its own side. Paralysis

of one side is due to injury of the opposite hemisphere of the cerebrum.

Location of Brain Functions.—Much has been learned in late years as to the location of special functions in the brain.

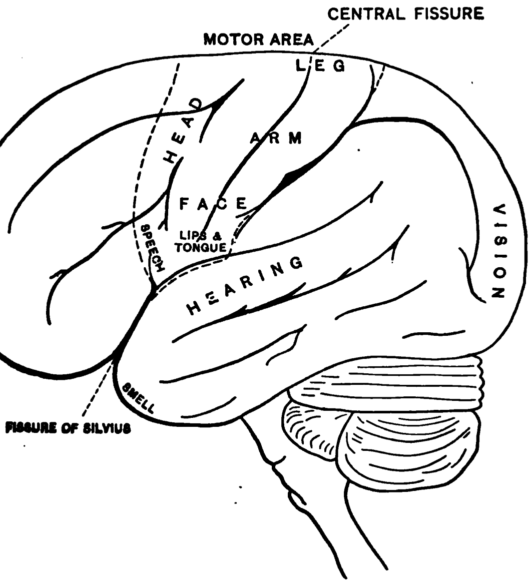


Fig. 93. Location of Brain Functions.

Some of the motor and sensory centers are shown in Fig. 93.

Connection of Brain Centers.—These different brain centers are connected by nerve fibers, and through these connecting fibers we produce various actions as a result of sensations. For instance (see Fig. 94), nerve impulses come through the nerve of hearing to the auditory center, and we have hearing; this center is connected with the speech center; and, as a result, we send out nerve currents to the

organs of speech, and thus we speak in response to what we hear. Currents from the eye reaching the visual center may connect with the writing center, and we send out currents by which we write in response to what we have read.

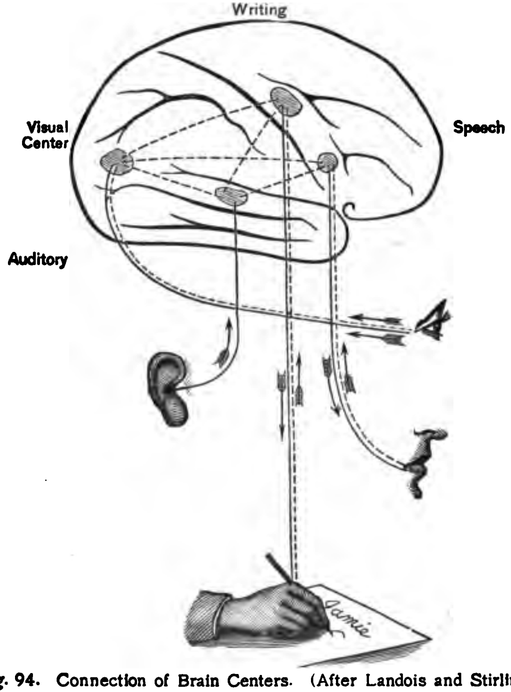


Fig. 94. Connection of Brain Centers. (After Landois and Stirling.)

Left Hemisphere Better Developed. — The "speech center" is in the left hemisphere; the right eye and ear, which connect with the left brain, are better developed than the left, and in general the left hemisphere seems superior (in right-handed persons) to the right.

The Function of the Cerebellum. — The cerebellum is the center for regulating the actions of the skeletal muscles.

When we walk or run, or even stand still, a number of muscles must act, and act in concert. The nerve impulses originate in the cerebrum, but the cerebellum is the center for harmonizing the action of these various muscles. When the cerebellum is injured, an animal staggers instead of walking steadily.

Functions of the Spinal Bulb. — The spinal bulb is the enlarged part of the spinal cord which is within the cranium. From it arise all the cranial nerves except the first five pairs. The spinal bulb is also the center for the control of respiration, of circulation, of swallowing, and perhaps for many other processes.

Brain Work and Brain Rest. — Sleep is not merely rest for the body; it should be complete rest for the brain. In so far as there are dreams, it would seem to indicate a partial activity; that is, incomplete rest. The brain, like the muscles, needs exercise, and it also needs regular periods of rest. If a nerve cell is not kept active by the passage of nerve impulses through it, it usually dwindles away, and may entirely lose its power.

Sleeplessness. — Intense brain work, without sufficient sleep, is likely to lead to sleeplessness, as when one has some subject of special study in hand and either will not or cannot throw it off. Perhaps inventors are as subject to this sort of trouble as any one class of men. Keeping the blood continually in the brain is likely to lead to a permanent congestion, or inflammation, that may cause serious, if not fatal, results.

Fatigue. — It is stated that brain workers need more sleep than those who work chiefly with the muscles. Fatigue of the voluntary muscles is much more a matter of

nervous than of muscular origin. When one is completely "tired out," as he would say, if his mind can be aroused, as by some excitement, he will be found able to expend a good deal more muscular energy. So, too, many persons of slight muscular build, but of great "will power," are able to do more work with the muscles than others with larger muscles and less will. During fatigue the cell bodies are found to decrease in size, but there is no perceptible change in nerve fibers as a result of fatigue.

Blood Supply of the Brain. — Blood is supplied to the brain through four arteries: the right and left internal carotid arteries, and the right and left vertebral arteries. These arteries are so connected by cross-branches that if any three of them should be compressed, or the blood flow in them otherwise stopped, the fourth would still be able to give the brain blood enough for its work: When the brain is more active it receives a larger supply of blood. During sleep it is paler.

Cause of Fainting. — If the supply of blood to the brain is shut off, unconsciousness quickly follows. In the ordinary faint the blood supply to the brain has been reduced. It is due to checking the action of the heart from some emotion, or bad air, as in a close room; severe pain may be the cause; a blow over the pit of the stomach may stop the heart by reflex action.

Apoplexy. — Apoplexy is caused by rupture of a blood tube and the formation of a clot that presses on the brain.

Meningitis. — Meningitis is an inflammation of the membranes immediately surrounding the brain or spinal cord or both.

Summary. — 1. The outside of the brain consists of gray matter, the inside of white matter.

2. The twelve pairs of cranial nerves are distributed to the head, with the exception of the tenth and part of the eleventh.

3. The cranial nerves include the senses of sight, smell, taste, and hearing.

4. Each hemisphere of the brain is connected with, and has chief control of, the opposite half of the body.

5. The gray matter of the cerebrum is the seat of the will, sensation, thought, and emotion.

6. The cerebellum regulates voluntary motion.

7. Many of the cerebral functions have been located.

8. The brain needs rest. In sleep less blood flows through the brain.

9. Work reduces the size of nerve cells. During rest they increase again.

Questions. — 1. Is there any special reason why the "speech center" should be in the left cerebral hemisphere?

2. Why does a light lunch sometimes enable one to go to sleep after mental work?

3. Why is it uncomfortable to hold the head down?

4. How does the nervous system resemble a telegraph system? In what respects are the two unlike?

5. Name some remedies for sleeplessness.

CHAPTER XXII.

THE SENSES.

THE GENERAL SENSES. — TOUCH AND TEMPERATURE SENSE.

Afferent and Efferent Nerve Currents. — Up to this point we have been studying efferent, or out-going, nerve currents, such as control muscles and glands. Now let us turn to the in-coming, or afferent, currents; for it is by means of the afferent currents to the brain that we get all our sensations. In other words, it is through these currents that we get all our knowledge.

Two Classes of Sensations. — There are two classes of sensations, the special and the general. The special senses include sight, hearing, taste, smell, touch, and temperature sense. Among the general sensations are hunger, thirst, fatigue, nausea, satiety, faintness, pain, muscular sense, etc.

Special Sensation due to External Force. — Sensations from the organs of special sense are due to the action of an external force. For instance, sound waves entering the ear affect the nerves of hearing, and we have a sensation of hearing. Light acting on the optic nerve gives sight.

General Sensations due to Conditions within the Body. — There are nerves of general sensibility in all parts of the body. The endings of these nerves are acted on by the blood and lymph. Currents are all the time coming through

these nerves to the brain. But ordinarily we are not conscious of them. If the body is in need of food, the messages are stronger and we have a sensation of hunger. If the poisonous waste matters are not removed by the organs of excretion, their presence in the lymph is reported to the brain, and we have a feeling, perhaps of fatigue, or of decided discomfort, or even of pain.

The Muscular Sense. — In judging the weight of a body by holding it in the hand, our estimate is the result of sensations aroused by nerve impulses from the organs used. There are afferent nerve fibers with endings in (1) the skin, (2) the muscles and tendons, and (3) the joints. In holding out the arm and in moving it up and down, all three of these sets of nerve endings are stimulated, and impulses are conveyed to the brain producing the muscular sense.

Dependence of Sight on Muscular Sense and Touch. — It is difficult to realize the importance of the muscular sense. An illustration of the assistance which touch and the muscular sense give to the sense of sight is furnished in the case of a boy who had been blind from birth, and received sight at the age of twelve years by means of a surgical operation. At first he could not distinguish a globe from a circular card of the same color until he had touched them. He knew the peculiar features of the dog and the cat by feeling, but not by sight. Happening one day to pick up the cat, he recognized for the first time the connection between the new sense of sight and the old familiar ones of touch and the muscular sense. On putting the cat down he said, "So, puss, I shall know you next time."

Pain. — The nerves of general sensibility give information of the state of nutrition in the tissues and the condition of the body as a whole. Ordinarily we are not aware of these nerve currents. When they become stronger than usual they give rise to feelings of general discomfort, such as fatigue, depression, restlessness, etc. When the currents become stronger still, we have pain.

Use of Pain. — Pain is a warning of over-use or injury. The milder nerve impulses that cause slight discomfort ought to be sufficient to call attention to the condition. But often these first reports are neglected. For instance, over-use or abuse of the eyes may cause irritation, that is allowed to go unheeded. The person may show the effect, by rubbing the eye, but, being absorbed in study, may fail to stop reading and go on until there is actual pain. When the first warnings are not heeded, pain follows and *demands* attention.

Pain in the Skin. — While the internal organs are ordinarily without feeling, the skin is especially sensitive. The skin senses stand guard at the outposts of the body's camp, and give warning of approaching danger. No enemy may enter without being discovered by these keen sentinels, and the alarm is given. In amputating a limb the chief pain is in cutting through the skin. It is a comfort to know that the more severe wounds do not cause pain in proportion to their extent.

Hunger and Thirst. — The cause of these sensations in a healthy body is plainly the need of food and water throughout the system. The sensation of thirst seems to be in the throat, and the longing may be somewhat relieved by merely moistening the throat. So hunger may, for the time, be appeased by filling the stomach with indigestible material. But the sensation soon returns. The system has a crying need, and it is not to be put off. That these sensations are really demands made by the body as a whole may be shown by the fact that they are permanently relieved by introducing food and water into the body (by the rectum, for instance), in which case the throat and stomach have nothing given them directly.

Since, however, food and drink naturally enter by the throat and stomach, the mucous membrane of these organs has become the spokesman of the body.

What we learn by touching Objects. — Let one person rest the hand flat on the table, palm upward, and close the eyes. An object placed on the palm, by another person, may give rise to various sensations, so that it may be described as rough or smooth, light or heavy, hot or cold, wet or dry, etc. If now the thumb and fingers are raised and applied to the object, more definite information will be gained as to its shape, size, surface, etc. Now raise the object in the hand, and further appreciation will be gained as to its weight. These experiments show that several sensations are involved in the handling of objects, and that the knowledge so gained is complex.

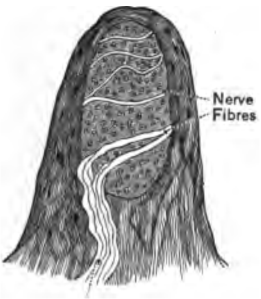


Fig. 95. Papilla of Skin with Touch Corpuscle.

Cutaneous Sensations. — The sensations from objects resting on the skin of the hand may all be referred to impressions made on nerve endings in the skin, and are called *cutaneous sensations*. They include: (1) the pressure sense, or touch proper, (2) the temperature sense, and (3) pain.

Nerve Endings in the Skin. — The skin consists of two layers, the epidermis and the dermis (see Figs. 64 and 65). In the papillas of the dermis are nerve endings called *touch corpuscles* (see Fig. 95).

Pressure on the skin affects these nerve endings, and starts impulses that pass along the sensor fibers, through the spinal cord, to the brain, and give us sensations of touch. If a nerve fiber is touched, not at the end, but somewhere along its course, we get a sensation, not of touch, but of pain.

The Sense of Touch. — Of the special senses the most general is that of touch. Seeing and hearing, taste and smell, belong to very limited parts of the outside of the body, but we have the power of feeling all over the surface of the body. Except in the mouth and nose, we get little, if any, sense of touch from any organ but the skin. The lining of the digestive tube and the internal organs generally lack this sense.

The Pressure Sense. — The sense of touch, proper, is strictly a *pressure sense.* If we test the skin to find what regions are able to detect the least pressure, it is found that the forehead is most sensitive, and nearly equally so are the temples, back of the hand, and forearm.

Location of Touch Sensations. — Each small spot of skin has its own nerve endings and each nerve fiber connects with a particular part of the gray matter of the brain. The brain can therefore tell where each nerve current came from, and thus we locate a sensation.

Accuracy in locating Touch Sensations. — The accuracy varies, and is ordinarily keenest where the nerves are most numerous. Where the sense of locality seems to be improved by cultivation, this appears to be due to keener perception in the brain cells, and not to changes in the nerves or nerve endings. This is shown in the fact that if the fingers of one hand become more skilled in touch by prac-

tice, it will be found that the fingers of the other hand, without special training, are also improved.

Test by Compass Points. — The delicacy of localizing touch is usually tested in this way. The blunted points of a light pair of compasses are allowed to rest gently on the skin of various parts of the body. If the two points are very close together, they will be *felt as one* pressure. That part which can best distinguish, as two points of touch, these blunt points, is considered the most sensitive. By this test the tip of the tongue is the most sensitive, being able to distinguish, as two separate points of contact, the tips of the compasses when only one twenty-fifth part of an inch apart. Following is the order of degrees of sensitiveness: tip of tongue, tips of fingers, lip, tip of nose, eyelid, cheek, forehead, knee, neck; while the middle of the back seems least sensitive.

Reference of Sensation to the Region of Nerve Endings. — If the "funny bone," or "crazy bone," be hit, *i.e.* if the ulnar nerve be bruised against the bone, sharp pain may be felt in the wrist and hand, and soreness of these parts may be felt for days, though they are not in the least injured, but only the nerve at the elbow. The currents along this nerve rouse sensations that we have learned to locate at the endings of the nerve fibers. If, then, owing to injury, the currents start from the elbow, the brain still refers them to the nerve endings in the hand and wrist. So, too, after amputation of a hand or foot, there may for years be sensations referred to the missing member, probably due to irritation of the nerves of the stump.

The Temperature Sense. — Many cases are on record in which, from accident or disease, the sense of touch was lost and the temperature sense retained, or *vice versa*.

Such facts have led to the belief that the temperature sense is distinct from that of touch, and has its own nerve fibers and nerve endings.

Summary. — 1. The special senses result from the action of external forces, such as light, heat, etc.

2. General sensations are referred to our bodies and their condition.

3. The muscular sense depends on impulses from muscles, tendons, and joints.

4. The muscular sense and touch aid the sense of sight in giving us correct perceptions of size and form.

5. Pain is a general sensation. It is a warning — the cry of a sentinel that an enemy has passed the picket line.

6. Hunger and thirst indicate the need of food and drink. They are local signals of a general want.

7. The cutaneous sensations are touch, temperature sense, and pain.

8. There are touch corpuscles in the papillas of the dermis.

9. Touch is the most general of the senses.

10. Touch proper, or pressure sense, is tested by perception of pressure.

11. Touch localization is tested by discrimination as to the distance of two points of contact.

12. Temperature is discerned by a special set of nerve fibers.

13. Sensations are referred to the region of the nerve endings.

Questions. — 1. What is the explanation of tickling.

2. Where does the change occur by which we become more skilled in the sense of touch ?

3. Why does an emotion, such as shame, make one feel hot ?

4. If we had no sense of pain, what might result ?

5. If we pass by a meal time without eating why does the sense of hunger usually disappear ?

CHAPTER XXIII.

THE SENSE OF SIGHT.

Protection of the Eye. — The eye is set well back in its socket and guarded by three bony projections, — the brow, cheek bone, and the bridge of the nose. It is further protected by the eyelids and eyelashes.

The Lacrymal Secretion. — The lacrymal gland, or tear gland, is just above the outer angle of the eye, and pours its secretion over the eyeball. The lids serve as curtains to admit or shut out light, and, by winking, wash the eye. It is as though a man were kept all the time in front of a plate-glass window, with water and rubber scraper, to keep it clean and bright. The lacrymal secretion is ordinarily carried off into the nasal cavity as fast as it is made. If the ducts are stopped, or if the secretion is formed very rapidly, the liquid overflows on the face as tears.

The External Parts of the Eye. — The "white of the eye" is the sclerotic coat. It has blood tubes, but ordinarily they are not conspicuous. The front part of the eye ball is covered with the cornea. This is transparent, and the color of the iris shows through the cornea. In the center of the iris is the hole, or pupil, by which light enters the interior of the eye.

The Conjunctiva. — The front of the eyeball is covered by a thin, transparent, mucous membrane, the conjunctiva, which turns back and lines the inside of the eyelids. It is very sensitive.

Movements of the Eye. — There are six pairs of muscles which move the eyes to right and left, up and down, and give rotary movements. The two eyes move in the same direction at the same time, though in looking at near objects the two eyes both point inward, so that one appears cross-eyed.

Dissection of an Eye. — The muscles and external parts of the eye may readily be seen by examining the eye of a rabbit in its natural position and then dissecting it out. A beef eye should be obtained from the butcher and the structure of the eye learned by following the description.

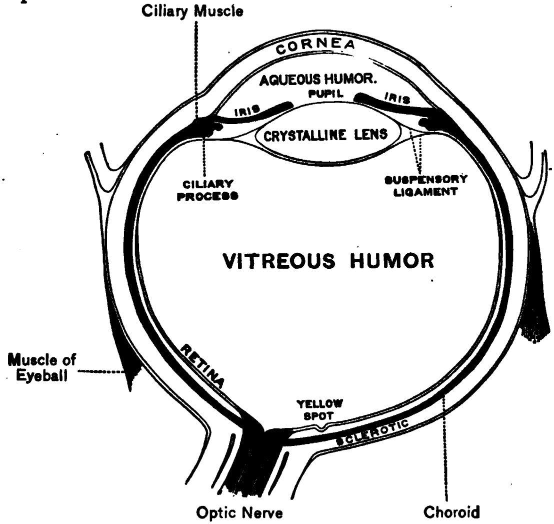


Fig. 96. Horizontal Section of Right Eye.

The Coats of the Eye. — There are three coats, the outer or sclerotic, the middle or choroid, and the inner or retina.

The Sclerotic Coat. — This is of a dull white color, constituting the "white of the eye." It is thick and tough, holding all the contained parts firmly and furnishing sufficient strength for the attachment of the muscles that move the eyeball.

The Choroid Coat. — The middle coat of the eye is the choroid. It is thinner than the sclerotic and of much more delicate structure. It is full of blood tubes, and has an inner lining of dark color to prevent the reflection of light in the eye, just as most optical instruments are painted black on the inside.

The Retina. — The retina is an expanded part of the optic nerve and forms an inner coat that lines all but the front part of the eye. It is a thin, translucent film, somewhat like the film that forms over the white of an egg when it is first dropped into hot water. It is very delicate and easily torn. The retina is the only part of the eye that is sensitive to light, and on it the images must be formed to produce distinct vision.

The Cornea. — The clear front part of the eye is the cornea. It is a continuation of the sclerotic coat and is more bulging than the rest of the front of the eye, as can be seen by taking a side view of the eye, or by noticing some one who closes the eyelids and rolls the eyes about.

The Iris. — This is the part that gives the color to the eye, or if the pigment that gives the color is lacking, the blood gives the pink color seen in albinos. The iris is a forward continuation of the choroid coat.

The Pupil. — Most of the light that passes through the transparent cornea is stopped by the opaque iris. But in the center of the iris is a round hole through which light enters the interior of the eye. The pupil looks dark because it is the only opening into a dark room.

Regulation of the Amount of Light admitted into the Eye. — Hold a hand glass between the face and a well-lighted window. Note the size of the pupils. Quickly turn toward the darkest part of the

room. The iris has circular muscle fibers that make the pupil smaller when there is too much light for the eye, and when the light is feeble the pupil opens wider.

The Aqueous Humor. — There is a small space between the cornea and the iris. In this space is the clear, watery aqueous humor.

The Vitreous Humor. — All but the front part of the space within the eye is filled with a clear, jelly-like substance, the vitreous humor.

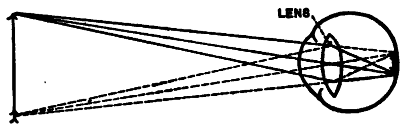


Fig. 97. The Formation of an Image on the Retina.

The Crystalline Lens. — Just back of the iris is a double-convex lens, clear as crystal, and of about the consistency of a gumdrop. It is less convex on the front surface.

Experiment with Lens to show Inversion of Image. — Take a double-convex lens or any hand magnifier. Hold this up at the rear of the room and catch the inverted image of the window on a piece of paper held back of the lens. This illustrates how the image of an external object is formed by the crystalline lens upon the retina of the eye.

Experiments to illustrate the Adjustment for Distance. — (1) Stick a pin at each end of a book cover. Hold the book at about the usual distance for reading, so that the two pins are in a line with the eye. Look closely at the nearer pin, and the second pin will appear indistinct and double. Now look closely at the head of the farther pin. The nearer one may be seen doubled, but not sharply. (2) Hold the tip of a pencil in a line with any object, say a picture, on a wall opposite. In looking at the tip of the pencil the picture is dim. Now look by the pencil at the picture, and the point of the pencil will be blurred and doubled.

Accommodation. — We cannot, at the same time, see distinctly a near and a distant object. When we look at

a near object the lens becomes thicker, and when we look at a distant object the lens becomes less thick. This adjustment is called *accommodation.*

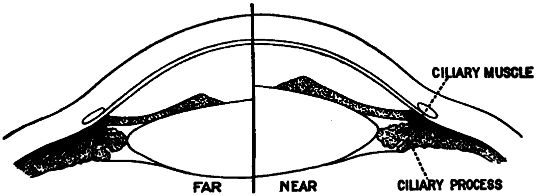


Fig. 98. Changes of the Lens in Accommodation.

The Blind Spot. — Light falling on the optic nerve itself has no effect in giving a sensation of light. If the light falls on the spot where the optic nerve enters the eyeball, we see nothing. Hence, this spot is called the *blind spot.*

Experiment illustrating the Blind Spot. — At the left (as looked at by the class) of a long blackboard make a bright circular spot, three inches in diameter, with white or yellow crayon. Beginning at the right of this write the figures 1, 2, 3, etc., along the whole length of the board, about eight inches apart. Let each pupil close the right eye and look at the bright spot. Then let each read the figures, passing slowly from one to another, at the same time noticing whether the bright spot can be seen. To succeed in this the eye must not be allowed to waver. Have the pupils tell when the bright spot disappears, then read on, and note when the spot reappears.

Another Experiment. — In this experiment shut the right eye, and be careful not to let the eye waver.

* Read this line slowly. Can you see the star all the time? If the star does not disappear before reaching the end of the line, let the eye travel on to the right of the page, or hold the book nearer the face. In the human eye the optic nerve enters the eye not in the center, but nearer the nose, so that in turning the left eye toward the right at the proper angle, the image of the star falls upon the spot where the optic nerve enters. As this spot is insensitive to light, the star no longer appears.

The Structure of the Retina. — The retina is very complicated in its structure. No less than ten layers have been distinguished, as shown in Fig. 99. The rays of light pass through the retina, and produce their effect on the rods and cones which constitute the outer (back) layer; and the nerve impulses aroused by the light must return through the thickness of the retina to be conveyed along the nerve fibers of the innermost layer of the retina to the optic nerve.

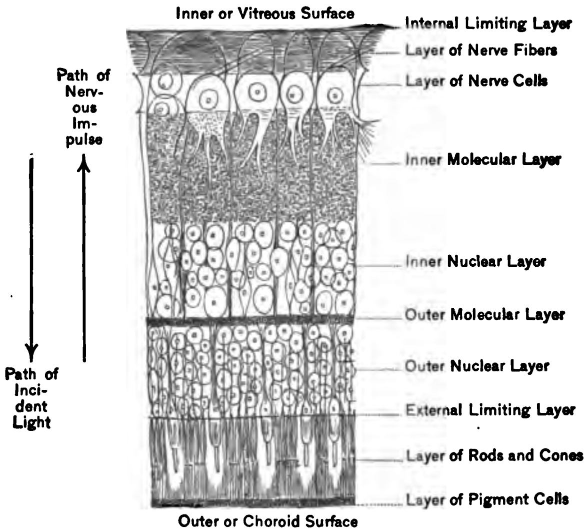


Fig. 99. Section of the Retina. (Waller.)

Importance of the Retina. — The chief structure in the eye is the retina. Without this all else is useless. If light falls on the retina, nerve impulses pass along the fibers of the optic nerve to the brain, and we have a sensation of light. But in order to see anything distinctly, the light must fall on the retina in such a way as to form a distinct image of that object. If the lens be removed, or becomes opaque, as in "cataract," we see objects very indistinctly, though we may be able to tell light from darkness. Light

from an object passes through the cornea, aqueous humor, lens, and vitreous humor, and the rays are so refracted as to form an inverted image on the retina.

The Optic Nerve not Sensitive. — The optic nerve, while capable of carrying nerve impulses that cause sensations of light, is not itself sensitive to light. If the optic nerve be cut, it does not give pain, but gives the sensation of a flash of light.

Sympathy between the Two Eyes. — While most of the fibers from each optic nerve cross to the other side of the brain, some fibers go to the same side of the brain. We can therefore better understand the close sympathy between the two eyes.

Color Blindness. — It is found that some persons cannot distinguish certain colors. Blindness to red and green are most common. This is a matter of importance among railroad men and sailors, where it is necessary to distinguish red and green signals.

Summary. — 1. The eye is protected by its bony surroundings, lids, lashes, tears, sensitiveness of the conjunctiva, etc.

2. The eye has three coats — sclerotic, choroid, and retina.

3. The pupil is a hole in the iris, and varies in size to regulate the amount of light admitted.

4. The cornea, aqueous humor, lens, and vitreous humor form an inverted image on the retina. The eye is a camera, darkened inside.

5. The lens changes its thickness for seeing at different distances.

6. Suitable glasses overcome many of the defects in eyesight.

7. The retina is an expansion of the optic nerve, and is exceedingly complicated in its structure.

8. The blind spot is the place where the optic nerve enters the eye.

9. The optic nerve is insensitive to light, but injury to it causes sensations of light.

10. Most of the fibers of the optic nerve cross to the other half of the brain, but some do not cross.

11. Defects in eyesight are much more common among civilized men than with the uncivilized.

12. The care of the eyes must be made a subject of study and careful thought by all reading people.

Questions. — 1. What is "cataract"?

2. What is the cause of "double vision"?

3. Why does the well eye sympathize with the affected one?

4. Why does looking at a bright light often cause a person to sneeze?

5. What is the condition of one who is "cross-eyed"?

6. Compare the pupils of a man, a cat, and a cow.

7. Does the color of the eye have any relation to the strength of eyesight?

8. Why is one blinded on entering a bright room from the dark?

9. Why is one going from a bright room into the dark unable to see at first, but gradually sees more distinctly?

10. Why can one not see well when the eye "waters"?

11. Should the lights which illumine a pulpit or platform be so placed that they can shine into the eyes of the congregation? How should they be arranged?

12. If each eye has a blind spot, why are there not blank spaces in the field of vision?

13. What advantage has a stereoscopic view over a single view? How are stereoscopic views made?

CHAPTER XXIV.

DEFECTS OF EYESIGHT AND CARE OF THE EYES.

DEFECTS OF EYESIGHT.

The Wearing of Glasses. — It will be noticed that many people, even children, nowadays wear spectacles or eyeglasses. The reason for this is probably not entirely because people's eyes are more defective now than they were fifty years ago; but partly because everybody, children and all, now have to use their eyes a great deal more than people did fifty years ago. Evidence of certain defects of the eyes for which glasses are worn show themselves more now than they did then; and therefore glasses have to be worn more.

Symptoms of Defective Eyes. — Many children suffer from headaches, or their eyes are red and watery. Sometimes they cannot plainly see the writing or drawing on the blackboards, or they appear to be stupid, or hold their books close to their eyes when reading or studying. Such children probably have some defect of the eyes which glasses will remedy. They should be sent to the oculist to have their eyes examined, and if it be found that they need glasses, they should wear them. It does not always follow that a person does not need glasses because he can see well; defects in his eyes may require such great effort of the eye muscles that control the focusing of the eyes as to cause headaches, nervousness, and other troubles which a properly fitting pair of glasses will remedy.

The Focus. — If an object is to be seen clearly, the eye,

like a photographic camera, has to be focused for the particular distance at which the object is placed. In the photographic camera the "focusing" is done by moving the lens nearer to or farther from the plate or film, according as the object to be photographed is farther from or nearer to the camera. To get a clear picture in photography, therefore, the length of the camera must be adjusted to the distance from the camera of the object to be "taken." When the object is a short distance from the camera, the "bellows" is pulled out and the camera is lengthened; when the object is farther away, the "bellows" is pushed in and the camera is shortened. If the camera is not properly "focused," a clear photograph cannot be taken. So also if one's eyes be not properly "focused," he cannot see clearly.

The Crystalline Lens. — The eye is "focused" in a different way. It cannot be made longer when we look at nearby things, or shortened when we look at more distant objects. Instead of this, the eye is "focused" by changing the shape of the "crystalline lens," which lies just back of the iris and the pupil, and which performs in the eye the same service that the glass lens does in the photographic camera; viz., it throws upon the retina, just as the camera lens does upon the photographic plate or film, an image of the object at which we are looking. Now, if we could change the thickness of the glass lens in the camera, making it thicker when photographing near objects and thinner when photographing those farther away, we should be doing in the camera just what is done in the eye when we "focus" it. In the eye, when we look at a nearby object, the crystalline lens becomes thicker; when we look at a more distant object, the crystalline lens becomes thin-

ner or flatter. It is made thinner and flatter by being pressed upon by elastic connective tissues between which it lies, just as a soft rubber ball will be made flatter if it be put between two layers of a handkerchief and the sides of the handkerchief pulled upon.

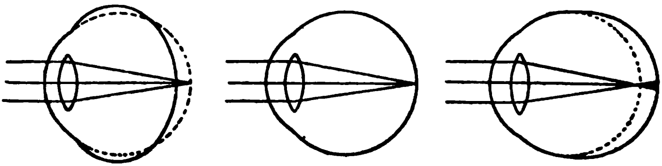
The Natural Focus. — In a state of nature the eye is used mostly for looking at distant objects, and not for looking at books and near objects, as we now have to do many hours at a time. Nature made the eye so that it would be focused for the distance by the elastic pull of the coats of the eyeball. Elastic coats not being made to work by nervous energy, as muscles are, never grow tired, as muscles do when they work. Nature made our eyes so that they would be focused for distant objects without any muscular action. Therefore, our eyes do not tire when we look at the distance; they are "resting." But in order that we may also clearly see near objects, our eyes are so made that the crystalline lens may be made thicker. Since in a state of nature the eyes are not used very often nor for very long periods in looking at near objects, the focusing for near objects is done by muscular action. Hence, the eyes become tired when they are used for long periods in looking at near objects.

"Accommodation." — Everybody has seen a lady's arm bag which closes by pulling the "puckering string." If the mouth of the bag were elastic, so that it would open itself if the string were not pulled, and if the string were a muscle, it would be something like the arrangement of elastic coats and muscles by means of which the eye is focused. Just behind the iris, where it is attached to the sclerotic coat of the eyeball, there is a very small circular muscle called the "ciliary muscle" or "muscle of accom-

modation." When it contracts, this muscle overcomes the pull of the elastic tissues, which causes the flattening of the crystalline lens, which, being elastic, becomes thicker, and the eye is focused for a near object.

Effect of Age. — As people grow older, the crystalline lens, like the other parts of the body, slowly loses its elasticity. Hence when the pressure is relaxed by the action of the muscle of accommodation, the lens cannot become thick enough to focus the eye for very near objects. For this reason middle-aged people cannot clearly see objects as near to the eyes as young people can. This is called "presbyopia," from two Greek words meaning "old-eye."

In order to see near things clearly, to read, etc., middle-aged people are compelled either to hold things off at arm's length, which is very inconvenient, or to put on glasses. But through these glasses they cannot see well at the distance, because the focus of the glasses is for a close object and cannot be changed.



(2) Far-sighted Eye. (1) Normal Eye. (3) Near-sighted Eye.

Fig. 100. Defects in Eyesight.

Far Sight. — It not infrequently happens that the eyeball is not long enough from the front to the back to permit of proper focusing for objects at a great distance without bringing into use the muscle of accommodation. In other words, a perfect eye is focused for great distances when the muscle of accommodation is at rest. In the

short eye, however, clear vision cannot be had at any distance, unless the muscle of accommodation be actively at work. Such eyes are called "far-sighted," or "hypermetropic," from three Greek words meaning "over-measured-eye."

On account of the fact that such an eye cannot see clearly at any distance without calling into constant action the muscle of accommodation, that muscle has no periods of rest except during sleep. It is apt to tire out, therefore, and the person who has such eyes may be subject to headaches or other nervous troubles. To overcome this he should wear glasses. Although his glasses are the same kind that "old-sighted" people wear, the "far-sighted" person can see clearly at the distance as well as near by with his glasses, while the "old-sighted" person can see clearly only close objects with his.

It not infrequently happens that the "far-sighted" person can see equally well at the distance with or without his glasses. But this is not a sign that he does not need glasses; on the contrary, it is a sign that he does need them; for if he did not need them, he could not see clearly with them.

If the eyes be too long from front to back, they cannot see clearly at a distance, but can see near objects clearly. Such eyes are called "near-sighted," or "myopic," from two Greek words meaning "mouse-eye," because near-sighted eyes, like the eyes of a mouse, are not infrequently quite prominent.

The eyes of most babies are "far-sighted," but as the rest of their bodies grow, their eyes also generally grow until they become only slightly "far-sighted." Sometimes the growth of the eyes does not keep pace with the rest of the body and the eyes remain quite far-sighted; in other

cases they grow too rapidly in one direction, from the front to the back, and become near-sighted. Children with either far-sighted or near-sighted eyes should wear glasses, — the far-sighted to avoid headaches and nervous troubles, the near-sighted to enable them to see plainly at a distance.

Near Sight. — When a child's eyes begin to grow near-sighted, there is danger that the near-sightedness will increase if special care is not taken to prevent it. The tissues of the child's eyes are comparatively soft and yielding. Children nowadays use their eyes a great deal for near work. The nearer any object is held to the eyes, the more the little muscles of accommodation pull upon the soft and yielding coats of the eyeball and tend to stretch them. Not only that, but the nearer any object is held to the eyes, the more the eyeballs turn inward; and the more they turn inward, the more they are pressed upon and squeezed by the six little muscles which move each eyeball. Thus pulled at from within and pressed upon from without, it not infrequently happens that children's eyes become too long from before backward, that is, "near-sighted."

Children can clearly see objects which they hold very near to the eyes, and for this reason frequently get into the habit of doing so. This is a very bad habit indeed, for it tends to make the eyes near-sighted, or, since it tires the muscles which turn the eyeballs inward and the muscles of accommodation, not infrequently causes headaches. This habit should be carefully and constantly corrected, and no child should be allowed to hold objects nearer than about fifteen inches from the eyes. If it cannot see plainly the smallest print at that distance, something is wrong with the eyes.

But the necessity for the wearing of glasses is not the

worst thing about near-sighted eyes. The tendency of near-sighted eyes is to grow more and more near-sighted unless great care is taken to prevent it. Even that, however, would not be very bad, for it would require only the wearing of stronger and still stronger glasses. But as the eyeball becomes more near-sighted, it becomes longer; and as it becomes longer, the membranes of which it is composed, especially the retina and the choroid coat, become more and more stretched and pulled upon, until they may even become diseased or pull apart, so that serious eye trouble, even blindness, may result from uncared-for near-sightedness.

Near-sightedness may, therefore, become a disease of the eyes. In fact, a near-sighted eye may be looked upon as a diseased eye. As near-sightedness occurs practically only among civilized people, it may be called a disease of civilization, and one would naturally expect to find it most prevalent among those people who use their eyes most for near work. Such is the fact. The Germans, of all people, use their eyes most for near work, and among them near-sightedness is very common. Another defect of the eyes occurs when the clear front parts of the eye (cornea and lens) are unequally curved so that the rays of light do not converge properly in the eye, the image on the retina is blurred, and the person thus afflicted cannot see clearly. This defect in vision, which is called *astigmatism*, can be corrected by specially prepared glasses.

Importance of Proper Glasses.— It will thus be seen that glasses are very frequently a necessity for children. Nervous, suffering, peevish, backward children, unable to keep up in their studies, are often changed into sturdy, happy, bright pupils who keep pace with their classes, simply by

fitting them with proper glasses. But as the proper fitting of glasses is not a simple thing, the child should be taken to an oculist, and glasses should not be purchased of peddlers. Ill-fitting glasses may be worse than none at all.

THE CARE OF THE EYES.

1. **Objectionable Light.** — In reading we wish light from the printed page. Hence we should avoid light entering the eye from any other source at this time. While reading, then, do not face a window, another light, a mirror, or white wall. White walls are likely to injure the eyes. Choose a dark cover for a reading table. Sewing with a white apron on has injured the eyes. Direct sunshine very near the book or table is likely to do harm.

2. **Position in Reference to Light.** — Preferably have the light from behind and above. Sitting under and a little forward of a hanging lamp will allow the light to fall on the book and keep it away from the face. In reading by daylight avoid cross-lights so far as possible.

3. **Electric Light.** — The incandescent electric light has advantages in throwing the light downward and in giving out little heat; but owing to its irregular illumination (due to the shadow cast by the wire or filament), it is not well suited for study or other near work. For this purpose an Argand gas or kerosene burner is much to be preferred, since it throws a soft, uniform, and agreeable light upon the work.

4. **Reading Outdoors.** — Reading out of doors is likely to injure the eyes, especially when lying down. To read while lying in a hammock is bad. Too much light directly enters the eye, and too little falls upon the printed page.

5. **Reading Heavy Books.** — Do not hold the book or work nearer the eyes than is necessary. So far as possible avoid continuous reading in large or heavy books by artificial light. Such books being hard to hold, the elbows gradually settle down against the sides of the body, and thus the book is held too close to the eyes, or at a bad angle, or the body assumes a bad position.

6. **Resting the Eyes.** — Frequently rest the eyes by looking up and away from the work, especially at some distant object. One may rest the eyes while thinking over each page or paragraph, and thus really gain time instead of losing it.

7. **Strength of Light.** — Have light that is strong enough. At twice the distance from a lamp the light is only one fourth as strong. Reading just before sunset is not wise. One is often tempted to go on, not noticing the gradual fading of the light.

8. **Evening Reading.** — Do the most difficult reading by daylight, and save the better print and the books that are easier to hold for work by artificial light. Writing is usually much more trying to the eyes than reading. By carefully planning his work one may economize eyesight. Weak eyes, by proper care, may outlast and do more work than those naturally stronger, but injured by abuse. Reading before breakfast by artificial light is usually bad.

9. **Reading during Convalescence.** — Many eyes are ruined during convalescence. At this time the whole system is weak — including the eyes. There is a strong temptation to read, perhaps to while away the time, perhaps to make up for lost time in school work. This is a time when a friend may show his friendship.

10. **Irritation of the Eyes.** — If one finds himself rubbing his eyes, it is a sign that they are irritated. Stop reading, find the cause, and do not read on unless the irritation ceases. If any foreign object, as a cinder, lodges in the eye, it is better not to rub the eye, but to draw the lid away from the eyeball and wink repeatedly; the increased flow of tears may dissolve and wash the matter out. If it be a sharp-cornered cinder, rubbing may merely serve to fix it more firmly in the conjunctiva. If it does not soon come out, the lid may be rolled up over a pencil, taking hold of the lashes or the edge of the lid. The point of a blunt lead pencil is a convenient and safe instrument with which to remove the particle.

11. **Keep the Eyes Clean.** — Be careful to keep the eyes clean. Do not rub the eyes with the fingers. Aside from consideration of rules of etiquette, there is danger of introducing foreign matter that may be very harmful. It is very desirable that each person have his individual face towel. By not observing this rule certain contagious diseases of the eyes often spread rapidly.

CHAPTER XXV.

TASTE, SMELL, HEARING, AND THE VOICE.

Uses of the Sense of Taste. — The sense of taste helps us in judging of the fitness of food. By reflex action the taste of agreeable substances aids in digestion by stimulating the glands, especially the salivary glands.

The Papillas. — The surface of the tongue is covered with papillas. Most of them are slender, and like the papillas of the skin, are organs of touch. Scattered among these are larger papillas in which are the endings of the nerves of taste.

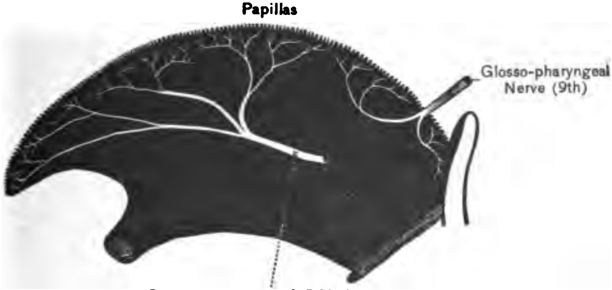


Fig. 101. Nerves and Papillas of the Tongue.

The Nerve Supply of the Tongue. — The nerves of taste are the glosso-pharyngeal, distributed to the back part of the tongue, and the gustatory in the front part. The tip of the tongue seems to be most sensitive to sweets and salts, the back part to bitters, and the sides to acids.

Solution Necessary for Tasting. — Substances must be dissolved before they can be tasted. If the tongue be wiped dry, and a few grains of salt or sugar be placed on it, the taste will not be perceived for a little time. Insoluble substances give no taste.

Flavors. — What we call flavors affect us more through the sense of smell than through taste. If the nose be held shut, a piece of onion placed on the tongue does not produce what we usually call the taste of the onion. By holding the nose we may get rid of the disagreeable part of taking certain medicines. Let the pupil experiment with various substances as above indicated.

The Sense of Smell. — The nerves of smell, the olfactory nerves, are distributed in the walls of the nasal passages. The sense of odor gives us information as to the quality of food and drink, and more especially as to the quality of the air we breathe. Hence we find the organ placed at the opening of the respiratory passages, and close to the organ of taste.

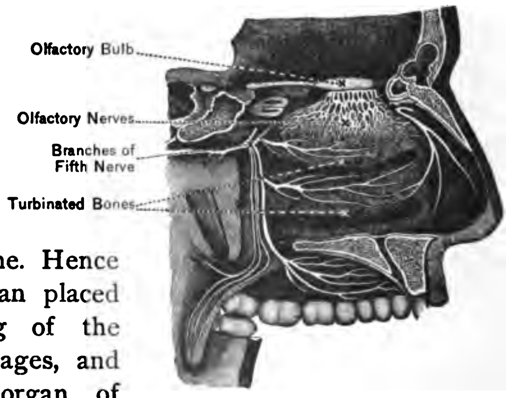


Fig. 102. Nerves of the Outer Wall of the Nasal Cavity.

Why we Sniff. — In quiet breathing the air passes along the lower air passages just above the hard palate. When we wish to test the quality of the air, we sniff, that is, make a sudden inspiration by jerking the diaphragm down, and air from the outside then rushes into the upper nasal passages, over the walls of which the olfactory nerves are spread in the mucous membrane. In inflammation, as from a cold, the narrow nasal passages, especially the upper, are often closed.

The Parts of the Ear. — The parts of the ear are the external, the middle, and the internal ear.

The External Ear. — The external ear gathers the sound waves, and directs them into the opening of the ear, but the loss of the external ear does not seriously interfere with hearing. The passage leading inward from the ear extends about an inch, and is then completely shut off

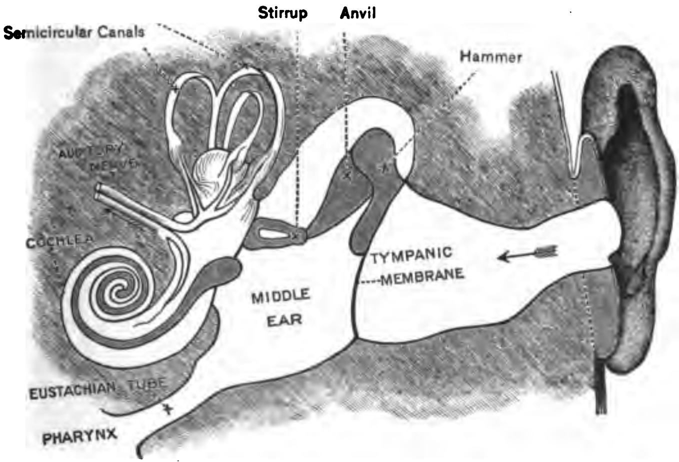


Fig. 103. Structure of the Ear.

from the cavities beyond by a thin membranous partition, the tympanic membrane or drum skin. This passageway is guarded by hairs, and is further protected by wax secreted by glands of the lining.

The Middle Ear. — Beyond the membrane of the tympanum is a cavity called the middle ear. Extending across the cavity of the middle ear is a chain of very small bones, the hammer, anvil, and stirrup, the hammer being attached to the inner surface of the membrane of the tympanum,

and the stirrup being fastened by its base to the wall of the internal ear.

The Eustachian Tube. — The middle ear communicates with the pharynx by means of a narrow tube called the eustachian tube. It admits air to equalize the pressure on the two sides of the tympanic membrane. This tube is closed most of the time, but opens when we swallow.

The Internal Ear. — The internal ear consists of several complicated cavities and tubes which contain a liquid in which rest the nerves. The principal cavity is the cochlea, or snail-shell cavity, in which the nerve endings are connected with an exceedingly complicated apparatus.

The Production of Sound. — Sound waves set the drum skin or membrane of the tympanum in vibration; the vibrations are conveyed by the chain of bones across the middle ear to the liquid of the inner ear. Through the complicated apparatus of the snail shell the vibrations of the liquid are made to start nerve impulses in the fibers of the auditory nerve, and when these nerve impulses are rightly received and interpreted by the brain, we have a sensation called sound.

The Equilibrium Sense. — Probably most of the senses contribute to the maintaining of the equilibrium of the body by giving information as to position, motion, etc., especially sight and the muscular sense.

Only that part of the auditory nerve which is distributed in the "snail shell" of the ear is now supposed to have to do with hearing. There seems to be good evidence that the semicircular canals inform us as to changes of the position of the body, and they are regarded as the seat of an "equilibrium sense."

The Care of the Ear. — In cleaning the ear no hard substance should be used; even the finger nail is likely to do harm. A moistened cloth should be used. It is not

well to stuff the ears with cotton. If there is any trouble with the hearing, of course a physician should be consulted without delay.

Colds and Deafness. — A cold often produces inflammation of the mucous membrane of the pharynx. This inflammation may extend along the eustachian tube to the middle ear and affect the hearing. See "Adenoids," p. 95.

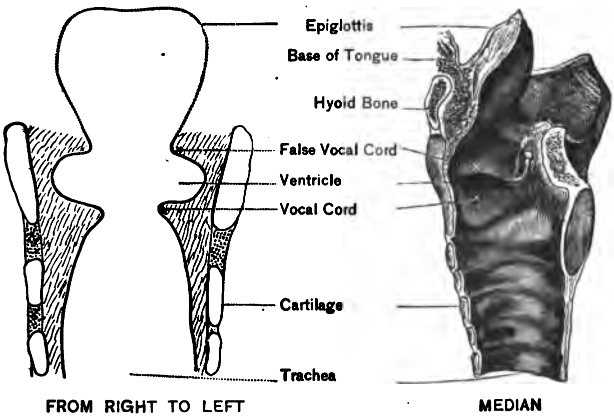


Fig. 104. Longitudinal Sections of the Larynx.

The Ear and the Voice. — The delicate structure of the ear is fully matched by the fine adjustment and range of the voice. The voice is produced in the *larynx* at the upper end of the windpipe. The projecting angle of the larynx is called "Adam's apple."

The Vocal Cords. — The vocal cords are not cord-like. They are mere ridges projecting inward from the sides of the larynx. They may be stretched to various degrees and placed in different positions, according to the sound that is to be produced.

The Position of the Vocal Cords. — While we are quietly breathing, the vocal cords lie back, like low ridges, against the sides of the larynx, and offer nearly the whole channel of the larynx for the free passage of air for breathing purposes. But when we wish to produce vocal sound, the vocal cords are made to stand out farther from the side walls, and interfere with the free passage of the air. The vocal cords are attached close to each other in front, but at the back of the larynx they diverge widely, forming a

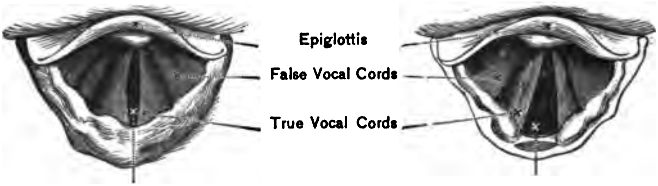


Fig. 105. The Vocal Cords, seen from Above

letter V, with the angle of the V just back of Adam's apple. "When changes in the voice or in breathing are being made, the white glistening vocal cords may be seen to come together or to go apart like the blades of a pair of scissors." In a high note the cords are close together and nearly parallel. As the air is forced past the edges of the vocal cords, they are set in vibration, and produce the sound called the voice.

Illustration of the Vocal Cords. — The principle of the action of the vocal cords can be illustrated by the common toy known as the squeaking balloon, or "squawker." Here the air is driven out past a band of rubber stretched across the inner end of the tube. If instead of one band with both edges free, we were to tie on the inner end of the tube two bands of rubber, each covering the outer edge of the tube, leaving the inner edge of the rubber free, and with the two bands touching at one end and considerably separated at the other end, we would have a pretty fair resemblance to the larynx.

Loudness of Voice. — The loudness of the voice depends on the force with which the air is driven past the cords, and on the size and condition of the cords themselves.

Pitch of Voice. — Pitch depends on the rapidity of the vibrations, which is determined by the length of the cords and their tension. Other things being equal, the size of the larynx would determine the pitch.

Voice and Speech. — The larynx by itself produces vocal sound merely. In speech the sounds produced in the larynx are much modified by the lips, tongue, teeth, cheeks, etc. We have voice as soon as born, but we only gradually acquire the power of speech. This distinguishes man from the animals below him.

Summary. — 1. Taste enables us to judge of the quality of food, and it indirectly influences digestion.

2. The tongue has two nerves of taste, the fifth pair of cranial nerves supplying the front, and the ninth pair the base.

3. So-called flavors affect the sense of smell more than that of taste.

4. The sense of smell tests food and air.

5. Agreeable odors promote respiration.

6. The ear consists of the outer, middle, and inner ear. In the inner ear are the endings of the auditory nerve.

7. The semicircular canals have to do with the sense of equilibrium and not with hearing.

8. Colds and catarrh often seriously affect hearing.

9. The larynx is very complicated. Various muscles move the cartilages and vary the length and tension of the vocal cords, and thus produce the varying degrees of pitch.

10. The vocal cords are not cords, but are band-like ridges on the sides of the larynx.

11. The higher animals have voice but not speech.

12. Whispering is speech without voice.

13. The larynx is affected by "colds" and catarrh.

Questions. — 1. How may the sense of taste be blunted?

2. What is the effect of inhaling menthol?

3. Does a person who is deaf in one ear hear "half as well" as before?

4. Which of the senses goes to sleep first when we go to bed?

5. In what order do the other senses go to sleep?

6. In what order do the senses waken in the morning?

7. Why does one become hoarse from hearing others shouting?

CHAPTER XXVI.

ACCIDENTS.—WHAT TO DO TILL THE DOCTOR COMES.

How to Stop Flow of Blood from Arteries.—In case of bleeding from an artery the blood comes in jets. Pressure should be applied between the cut and the heart. To know where to apply the pressure, study the course of the main arteries. By examining Fig. 32 it will be seen that the arteries to the arms pass down the inside of the upper arm. Here they come near the surface. By putting a thick book or roll under the armpit and pressing the arm down firmly, the artery may be compressed.

Bleeding from the Upper Arm.—In case of a deep cut in the lower part of the arm, a handkerchief should have a knot tied in it, and the knot placed over the artery; that is, on the inside of the arm just below the armpit. Pass the handkerchief around the arm and tie it loosely. Then run a stick through it, and twist till the knot is drawn tightly against the artery. Instead of a knot, a potato, or anything else to make a firm lump, may be used. (See Fig. 32.)

Bleeding from the Neck.—In studying the pulse, we found the carotid artery in the neck. If a deep cut has been made in the upper part of the neck, it may be possible to stop the flow by compressing the artery lower down the neck.

Wounds in the Thigh.—The femoral artery comes near the surface in the groin. Pressure may be applied here in the same way to stop bleeding from a cut farther down the thigh. In the angle back of the knee, pressure may compress the artery supplying the leg. In case of severe wounds, pressure should be applied immediately to the wound. Sometimes it is well to make a plug of cloth and press upon the cut.

Bleeding from Veins.—In case of bleeding from veins, holding the part up may check the flow. If necessary to apply pressure, it should be beyond the cut, instead of between it and the heart, as in the case of the artery.

Hemorrhage of the Lungs or Stomach. — Blood from the lungs is bright, frothy, and salty; from the stomach is usually dark and sour. In case of bleeding from the lungs or stomach, let the person rest quietly on a lounge or easy-chair. Give him some bits of ice to swallow, and call a physician.

Bleeding from the Nose. — Nosebleed may sometimes be stopped by pressing firmly at the base of the nose. Do not lean forward, as this position aids the flow. Sit up, and hold up the head, and hold a cloth under the nose. Apply cold water or ice to the nose and to the back of the neck. If this does not stop it, inject cold water, with a little salt or soda in it, into the nose. Often the flow may be stopped by pressing firmly on the upper lip at the sides of the nose. If these attempts fail, a long strip of cloth may be used to plug the nostril, pushing the cloth in a little at a time, and leaving the ends so it can be pulled out. This should not be removed till a long time after the flow is checked, as it may start the bleeding afresh. After an attack of this kind avoid blowing the nose, as this often starts bleeding again.

Treatment of Burns. — Plunge the burned part into cold water. As soon as possible apply a solution of cooking soda (a tablespoonful of bicarbonate of soda to a teacup of water); or lay a wet cloth on the burned part and put the soda on the cloth. Afterwards apply vaseline, and renew the vaseline till the wound is healed. A mixture of equal parts of sweet oil and limewater makes a good liniment for dressing burns.

Danger from Burning Clothing. — If the clothing takes fire, there is added to the danger of burning the body, the further risk of inhaling the flame and heated air. It is best to lie down and roll or wrap the body in any cloths at hand, — rugs, shawls, etc. Running serves to fan the flames. Hence, if a person whose clothing is on fire has lost presence of mind and starts to run, throw him to the ground, putting a wrap of some kind around the body at the same time if possible. Rolling on the ground or floor in itself would very likely put out a small flame.

Treatment of Fainting. — Lay the body flat on the back. Keep the crowd away, and give plenty of fresh air. Loosen the clothing about the neck and waist. Sprinkle cold water on the face, but do not drench the body with a quantity of water. Apply smelling salts (ammonia) to the nostrils; rub the limbs toward the body. If these remedies do not soon restore consciousness, send for a physician. A faint is not usually

a serious matter. Bad ventilation, disagreeable odors, or even the oversweet odors of such flowers as the tuberose, may cause fainting.

Broken Bones. — Keep the patient as quiet as possible till the physician arrives. If there is inflammation, cold water may be applied. Cooling applications are desirable in case of severe bruises. If it is necessary to carry the patient, lay him on a board, or at least keep the injured part as quiet as possible; a cane or umbrella may be tied alongside a leg, and supported by a pillow or a coat. Otherwise the sharp ends of the bones may cut the flesh or even blood-tubes.

Sunstroke. — Lay the patient in the shade and pour cold water over the head.

Fig. 106. Resuscitation from Drowning. (Lincoln, 3 Figures.) (Position I.)

TREATMENT OF THE DROWNED.

(As given by the Michigan Board of Health.)

RULE 1. *Remove all obstructions to breathing.* Instantly loosen or cut apart all neck and waist bands; turn the patient on his face, with the head down hill; stand astride the hips with your face toward his head, and, locking your fingers together under his belly, raise the body as high as you can without lifting the forehead off the ground (Fig. 106, Position 1), and give the body a smart jerk to remove mucus from

the throat and water from the windpipe; hold the body suspended long enough to count slowly, one, two, three, four, five, repeating the jerk more gently two or three times.

RULE 2. Place the patient on the ground face downward, and, maintaining all the while your position astride the body, grasp the points of the shoulders by the clothing, or, if the body is naked, thrust your fingers into the armpits, clasping your thumbs over the points of the shoulders, and raise the chest as high as you can (Fig. 107, Position 2) without lifting the head quite off the ground, and hold it long enough to count

Fig. 107. Resuscitation from Drowning.
(Position 2.)

slowly one, two, three. Replace him on the ground, with his forehead on his flexed arm, the neck straightened out, and the mouth and nose free. Place your elbows against your knees, and your hands upon the sides of his chest (Fig. 108, Position 3), *over the lower ribs, and press downward and inward with increasing force* long enough to count slowly one, two. Then suddenly let go, grasp the shoulders as before, and raise the chest (Position 2), then press upon the ribs, etc. (Position 3). These alternate movements should be repeated ten or fifteen times a minute for an hour at least, unless breathing is restored sooner. Use the same regularity as in natural breathing.

RULE 3. After breathing has commenced, restore the animal heat. Wrap him in warm blankets, apply bottles of hot water, hot bricks, or anything to restore heat. *Warm the head nearly as fast as the body lest convulsions come on.* Rubbing the body with warm cloths or the hand, and slapping the fleshy parts, may assist to restore warmth, and also the breathing. If the patient can *surely* swallow, give hot coffee, tea, milk. Alcoholic liquors are liable to produce depression. Place

Fig. 108. Resuscitation from Drowning.
(Position 3.)

the patient in a warm bed, and give him plenty of fresh air; keep him quiet.

Avoid Delay! — A moment may turn the scale for life or death. Dry ground, shelter, warmth, stimulants, etc., at this moment are nothing — artificial breathing is everything — is the one remedy — all others are secondary. Do not stop to remove wet clothing. Precious time is wasted, and the patient may be fatally chilled by the exposure.

First restore Breathing. — Give all your attention and effort to restore breathing by forcing air into, and out of, the lungs. If the breathing has just ceased, a smart slap on the face or a vigorous twist of the hair will sometimes start it again, and may be tried incidentally.

Before natural breathing is fully restored, do not let the patient lie on his back unless some person holds his tongue forward. The tongue by falling backward may close the windpipe and cause fatal choking.

Prevent friends from crowding around the patient and excluding the fresh air; also from trying to give stimulants before the patient can swallow. The first causes suffocation; the second, fatal choking.

Do not give up too soon: you are working for life. Any time within two hours you may be on the very threshold of success without there being any sign of it.

Learn to Swim. — Of course, persons who cannot swim ought not to go out in a boat without taking along some sort of a float that may serve as a life-preserver. Some of the rubber cushions serve well for this. Every father neglects his duty if he does not teach his children, girls as well as boys, to swim and to float. One cool, trained person may save the lives of a whole boat load.

When a Boat Upsets. — In case an ordinary rowboat is overturned, one should not attempt to climb into it or upon it. It takes very little to float a person in water, as the body is only a little heavier than water; in fact, if a person fills the lungs and lies back in the water his face and nose will keep above water, and a person (at any rate without clothing) can float in this way for some time if he breathes lightly. Few persons have been taught these facts, and most of those who have learned them lose their presence of mind, and waste their breath and strength in wild and fruitless splashing. If a boat be overturned, those who can swim should help those who cannot to get hold of the edge of the boat, but not permit them to climb upon it. A small plank will float a person if he does not try to lift much of his body out of the water.

Suffocation in Wells. — Persons are sometimes suffocated by carbon dioxid in wells and cisterns. Before going down into a well, it is a safe precaution to lower a lighted candle. If this is extinguished, a warning is given. If a second person goes down after one who has become unconscious, great care must be taken that two lives are not lost. A rope should be firmly tied about the body, a hook, attached to another rope, taken to catch into the clothing of the first, and the rescuer should be lowered quickly and brought up immediately. A small rope or large cord might be carried, by pulling which the signal is given to pull up. In resuscitating from carbon dioxid suffocation use

the same method as after drowning, except the first part, which is to remove water from the windpipe, etc.

Poisons and their Antidotes. — Several of the common drugs and remedies kept about the house are more or less poisonous. The proper antidote for each should be known and kept at hand. In the first place, all such materials should be kept locked up so they will not be taken by children, or by mistake, as in the haste of getting medicine in the night. Again, all grown persons in the family should be instructed as to the effects of each poison, and taught its antidote. As soon as any new poisonous drug is bought, it should be made a point to read up about it, and procure an antidote. Every one should know that strychnin causes spasms, that opium brings on stupor, with contracted pupils, etc.

Objects of Treatment. — Treatment aims at three things, (1) to get rid of the poison, (2) to neutralize what remains and prevent further action, (3) to remedy the effects already produced.

1. **Mustard a Common Emetic.** — The most common emetic is mustard; a tablespoonful in a cup of warm water; give half of it, following with free drinking of warm water, then give the rest of the mustard. Do not wait for it to dissolve, but stir quickly and give at once. Provoke vomiting by tickling the throat with a feather or with the finger. If the mouth of the patient cannot readily be opened, insert the thumbs inside the cheeks and back of the teeth. If mustard is not at hand, a strong solution of table salt will serve. In a few cases, such as poisoning by ammonia, lye, etc., it is considered best not to administer an emetic, but to try to neutralize the effect.

2. **Neutralize the Poison.** — To neutralize a poison this general rule should be known: an alkali may be neutralized by an acid, and *vice versa*. For example, lye with vinegar, carbolic acid with alcohol and whiting or magnesia, etc. Some acids and alkalis are always about a house.

3. **Give Something Soothing.** — After any irritant poison some mild and soothing substance should be given, — white-of-egg, milk, mucilage and water, flour and water, gruel, olive- or castor-oil. These materials are partly for neutralizing the poison, and are also soothing in their effect. If a patient is drowsy, some stimulant may be given, as strong coffee (after opium). Of course a physician should be sent for immediately, as the after-treatment is of great importance.

Wounds from Thorns and Rusty Nails. — Promote bleeding by rubbing and pressing the wound and bathing with warm water. Or suck the wound. This tends to remove any injurious matter. Apply poultices.

Bites of Cats, Dogs, etc. — If the animal is rabid (mad), suck the wound and cauterize quickly. A poker or nail heated red hot is best for cauterizing. If one cannot do this promptly, get lunar caustic with which to cauterize; strong acid or alkali, or a coal of fire, may be applied at once to the wound; the coal on a cigar may be used. Do not kill the animal if there is doubt. Keep it confined, and if it proves a false alarm much anxiety will be saved.

Snake Bites. — Apply ligatures around the part between it and the heart. Suck the wound (there is no danger in this if there are no sores or cracks in the skin of the mouth; venom is not a stomach poison). Then apply caustics, or a live coal. Wash the wound with vinegar or strong salt solution. If ammonia water is at hand, add five teaspoonfuls to a pint of water and drink this. Ammonium carbonate, ten per cent solution, is also highly recommended. A teaspoonful dose should be given immediately, and repeated twice at intervals of ten minutes. To bee stings, apply soda or dilute ammonia.

Poison Ivy. — The itching and discomfort may be relieved by bathing the part in a mixture of two teaspoons of carbolic acid (pure), two tablespoons of glycerin, one half pint of water or rose-water.

The Sick-room. — Every boy and girl ought to learn something about the care of the sick, as any one is likely to be called on to do this kind of work. Good nursing is often "half the battle." The patient should have a cheerful room, but the bed should be so placed that he will not face the light. Evidence of illness, such as medicine bottles, etc., should be kept out of sight so far as possible. While it is not best to deceive the patient as to his condition, there should at all times be kept up an air of cheerfulness and hope. If the physician can inspire with confidence, and the nurse give unflagging good cheer, the chances of recovery are greatly improved. Nothing sustains like hope. Keep the air of the room pure. Remove excreta and everything offensive just as soon as possible. Do not rely on *feeling* as to temperature, but keep a thermometer in the room.

Sympathy with the Patient. — One of the necessary characteristics of a good nurse is the power of imagination. "How would I feel, and

what would I like to have done, if I were in his place?" This feeling will lead the nurse frequently to raise the patient's head and turn the pillow — the coolness of the other side of the pillow is refreshing; to give sips of cool water; to see that the patient does not suffer for want of a bath.

Bathing the Sick. — In bathing a weak person only a part of the body should be moistened at a time; after this part is thoroughly dried, another part may be washed; it is often necessary to do all this work under the bed clothing.

Changing the Bedding. — In changing the bed clothing move the patient to one side of the bed, push the clothing along close to his body, and place the clean bedding on the other side; then move the patient back, remove the soiled linen, and smooth out the clean. It is often necessary to warm the sheets first; they should be thoroughly dry.

Follow Physician's Directions Faithfully. — Have the physician's directions written out plainly, as they may be forgotten; and if there is a change of nurses during the night there is less chance of mistake. Never let yourself get drowsy when acting as nurse. Get up and walk about, get a breath of fresh air, and if inclined to be drowsy do not allow yourself to settle back in an easy-chair. If watching all night, take a good lunch in the middle of the night; coffee may help to keep you awake.

Sweeping the Sick-room. — Do not allow the room to be swept with the ordinary broom. The room should have rugs that can be removed and shaken, and the floor wiped with a moist cloth. If the room is carpeted, it may be swept with moist salt, tea-grounds or coffee-grounds, sawdust, etc. Any dusting should be avoided; furniture may be wiped with a damp cloth.

Do not Whisper. — Do not whisper, as it disturbs more than talking, and also has an air of secrecy that rouses suspicion in the patient.

Food for the Sick. — Raise the head with the hand, or bolster the patient up, when giving drink; or if the patient is very weak, use a rubber or glass tube, so that he will not have to lift the head. The nurse should know how to prepare any food that may be needed during the night. An oil stove or gas stove is very desirable for cooking, or heating poultices, as an ordinary wood or coal fire is likely to die down,

making it impossible for the nurse to do this work quickly, as it is often necessary to take advantage of a favorable time, as when the patient wakens.

Care of Lamps. — Most lamps, when turned low, give off a disagreeable gas. It is better to have a very small lamp burning at full height than a large one turned low; sperm candles are recommended. Do not let the light shine into the patient's face.

To Prevent Sneezing. — It is well known that a sneeze may be prevented by firmly pressing on the upper lip. This may enable a nurse to keep from waking a very sick patient when, at a critical point, sleep is almost a question of life or death. And it is a convenient fact for any one to know. To prevent coughing, a sip of cold or hot water will relieve the tickling in the throat.

Summary. — 1. To stop flow of blood from an artery apply pressure to the wound, or between the wound and the heart.

2. To stop flow of blood from a vein apply pressure to the wound or beyond the heart.

3. Leaning forward promotes, instead of checks, nosebleed.

4. In case of a burn apply cooking soda.

5. If the clothing takes fire, lie down and roll, or wrap a rug or shawl about the body.

6. If a person with clothing on fire loses his presence of mind, seize, throw down, and wrap in any woolen clothing.

7. In case of fainting lay the body flat on the back, loosen clothing, give fresh air, and sprinkle lightly with cold water; if this does not revive, rub the limbs toward the body, hold to the nostrils smelling-salts (or ammonia), and send for a physician.

8. Before going down into a well, test the air by lowering a lighted candle.

9. Learn the antidotes of every poison in your house *as soon as it is bought*, and keep the antidote at hand.

10. Volunteer to help take care of sick friends, and learn to do this work well.

Questions. — 1. How does holding up the wounded part check bleeding?

2. What other methods of resuscitation from drowning are in use?

3. What are some of the poisonous substances commonly kept in the house?

CHAPTER XXVII.

VACCINATION.

Conditions before the Discovery of Vaccination. — Before the discovery of the value of vaccination by Dr. Edward Jenner in 1796, smallpox was so prevalent that nearly everybody had it, and many thousands died from it every year, while other thousands were left blind or terribly scarred. Jenner discovered that persons who have had a disease called vaccinia, or cowpox, are much less liable to be attacked by smallpox, and that, if they are so attacked, the disease is not apt to be severe or dangerous. Before Jenner made this discovery any person who had had a mild attack of smallpox was considered fortunate, as those who have had the disease once are not liable to have it again. Since nearly everybody had it before Jenner's time, those who had had a mild attack were looked upon as having escaped a very great calamity. Nearly everybody in those days was scarred more or less with smallpox pits. It was customary when servants were employed to hire none who had not had smallpox, so that the employer might not be put to the trouble and expense of having to take care of a smallpox patient. So universal was smallpox and so terrible were its results that it was proposed, before Jenner discovered the benefits of cowpox, to inoculate everybody with the virus from a mild case of smallpox, thus making sure that everybody should have it, in the hope that if the disease were thus acquired from mild cases it would be less dangerous. But Jenner's discovery that cowpox is a preventive of smallpox, and that cowpox is a comparatively harmless disease, soon changed the whole condition of affairs. Vaccination — that is, inoculation with the virus of cowpox, instead of inoculation with the virus of smallpox — became common.

Value of Vaccination. — The best medical authority in every civilized country in the world supports the proposition that vaccination, more than all other causes combined, accounts for the fact that nowadays in those places where it is thoroughly carried out smallpox is not a preva-

lent disease, that very few deaths result from it, and that one seldom sees a person who has been disfigured by it. And there are many illustrations in medical literature, both in olden and in modern times, of the fact that, when vaccination is thoroughly practiced, smallpox almost entirely disappears, to break out again when vaccination has been neglected, and to disappear again when vaccination is resumed. London has furnished such illustrations many times; and the same has happened in many other cities, such as Boston, Birmingham, Liverpool, and Montreal. In Montreal, for instance, vaccination had been generally practiced for many years, and there had been practically no smallpox in the city during that time. But, about forty years ago, many of the people of Montreal refused to permit their children to be vaccinated. When, in the winter of 1885, a colored Pullman-car porter arrived in Montreal sick with smallpox, the disease found a fertile field in which to spread. Before many months had passed thousands of the people of Montreal had had the disease, three thousand of them had died from it, and other thousands were left maimed and scarred. It was found, however, that, as is always the case, very few of those who had been vaccinated were attacked by smallpox, the disease taking as its victims almost solely those who had not been vaccinated.

Harmless. — Vaccination is practically painless and harmless. The disease it causes, cowpox, or vaccinia, is also, compared with smallpox, a harmless disease. Now and then somebody dies after being vaccinated. But out of the many millions who are vaccinated every year, only a very few die as a remote result of it. Without vaccination smallpox would be prevalent and kill thousands.

Those who are opposed to vaccination claim that it does not protect from smallpox; that it causes other diseases, such as tuberculosis, or consumption, scrofula, and tetanus, or lockjaw; that it is more dangerous than smallpox, which, they claim, cannot nowadays become epidemic because of the greater cleanliness and better sanitary conditions which surround us.

Medical Authority. — The fact still remains, however, that the best medical authority in all civilized countries maintains that none of the claims of those who oppose vaccination is founded on facts. The best medical authorities say that very few, if any, of the many millions who are vaccinated every year contract consumption or other disease from it. They show, also, that many people die every year

from lockjaw as the result of infection with the lockjaw poison absorbed through scratches no deeper than those inflicted in vaccinating. They point out that any open wound may become infected with the poison of lockjaw. Also that, while it requires only ten days for the poison of lockjaw to develop, in most of the very few cases that have followed vaccination the disease has broken out more than ten days after the vaccination operation was performed. This, they claim, proves that the lockjaw was not the result of vaccination, but, as may happen after any other scratch, resulted from the lockjaw poison finding an open wound through which to enter the body.

If proper care be taken thoroughly to cleanse the skin before vaccination is performed, if pure vaccine virus be used, and if the little wound and the vaccination sore be kept protected from infection with disease germs from the air, the danger from vaccination is very slight.

CHAPTER XXVIII.

STIMULANTS AND NARCOTICS.

Stimulants. — A stimulant, in the physiological sense, is anything which causes an increase of vital activity in any of the organs of the body.

Food is, therefore, a stimulant, because it increases the vital activity of the organs of the body. Heat and cold, in their first effects, are stimulants, for they increase the vital activity of the organs to which they are applied. To illustrate, either heat or cold will cause the skin first to whiten and then to redden, and heat will cause perspiration to flow from the sweat glands.

Alcohol, tobacco, opium, morphine, tea, coffee and many other things are also stimulants, because their first action after being taken into the body is to increase the vital activity of some of the organs. All the above-mentioned stimulants affect, among other organs, the heart, nervous system, and brain; and their effects are seen first in these organs.

Narcotics. — A narcotic, in the physiological sense, is anything which quiets the nervous system and brain, relieves pain, and produces sleep.

All narcotics are, in their first effects, stimulants; and all stimulants are, in their secondary effects, narcotics. So it may be said that stimulants are narcotics in small quantities and that narcotics are stimulants in large quantities.

To illustrate again with heat and cold: one of the effects of a hot bath is to redden the skin, showing its stimulating effect. In a little while, however, the whole body becomes languorous and sleepy. One of the effects of cold is to redden the skin; but, as every one knows, if the cold continue long enough, the person becomes drowsy and falls into a deep sleep. Where one "freezes to death" he dies in a profound sleep.

Effects of Large and Small Quantities. — Alcohol, tobacco, opium and morphine are all stimulants and all narcotics; they are stimulants when

used in small quantities and narcotics when used in large quantities. Thus, a glass of wine or beer sets the heart to beating more rapidly,—the stimulating effect; but many glasses of either will make him who takes them drowsy and finally put him into a drunken sleep,—the narcotic effect.

We look upon morphine and opium as examples of narcotics because they are used in medicines to quiet the nervous system, stop pain and produce sleep. Yet small doses of either have, apparently, only stimulating effects, for the reason that the various organs are able to resist the effects of small doses and, therefore, do not become narcotized.

A weary horse is whipped to make him go faster or pull harder. The faster he goes or the harder he pulls, the more tired he becomes, and, therefore, the more the whipping that is necessary to keep him going. The whip may be called a stimulant to the tired horse, because it produces an increase in his activity. But when the work is done, the horse is very tired indeed and requires a long rest before he can work well again. Indeed, if the horse be compelled, by the stimulating effect of the whip, to run or pull too hard and too long, he may fall down exhausted, and may even die.

Effect of Continued Use.—Alcohol, tobacco, morphine, or opium are, like the whip to the horse, stimulants, in their first effects, to the bodies of those who use them. Like the whip also, they will, if taken in too great quantities, bring even death to those who use them.

Even the most mettlesome and high-spirited horse would, if the whip were constantly used upon him, get so used to it that he would not work without being whipped. Worse than that, the more accustomed he gets to the whip, the more and the harder it must be used upon him, until, finally, he will not work unless he be whipped unmercifully all the time Such a horse is of no use, and his cruel master has spoiled one of man's best friends.

Any person who uses stimulants continuously is whipping his own body, as the cruel master does his horse. As in the case of the horse, the more the body is whipped, the more whipping it requires to make it do its work, until it will not work at all unless it be constantly whipped; that is, constantly under the influence of stimulants. A horse that will not work unless it is constantly whipped is a poor sort of a horse. A man who will not, or cannot, work unless he is under the influence of stimulants is rather a poor sort of a man. We call a person cruel who

whips his horse; a man is cruel to himself if he allows himself to get into such a condition that he must whip his body with stimulants to compel it to work.

Danger in Forming Habits. — Many people drink alcoholic liquors and never become drunkards. Yet many people do become drunkards. In fact, any person, particularly one who begins in youth and who continuously uses alcoholic liquors, is very liable indeed to become a slave to drink and die a drunkard. But those who continuously use alcoholic liquors run serious danger in other ways, even though they may never become drunkards. For alcohol goes into the blood when it is taken into the stomach, and, therefore, comes in contact with every organ of the body. The action of even small amounts of alcohol in the blood is very apt, if kept up for a long time, to produce disease of the kidneys, liver, stomach, heart, nerves and brain, and thus cause the death of those who, though never drunk, are still slaves to alcohol. These are well-known medical facts.

Especially Dangerous to the Young. — The danger from stimulants is especially great when used by young and growing persons. They require all the nervous energy that their bodies produce to keep their organs growing besides doing their proper work. If, therefore, these organs be whipped by stimulants, they become accustomed to them and will not, or cannot, properly work without them. The result is that the various organs of the body, especially the heart, brain and nervous system, do not develop properly. Worst of all, there is the greatest danger that such a person will become a slave to the particular stimulant he may be using. Thus it happens that so many boys and young men become drunkards. They drink wine, beer and whisky; their growing bodies cannot withstand the effects of the stimulation, and finally, before they realize it, they become habitual drunkards.

Stimulants both Unnecessary and Injurious. — That stimulants are not only unnecessary but even positively injurious is proven by the fact that no person who is training for any feat of strength, skill, or endurance, ever uses any of them, except, perhaps, a little weak tea or coffee. No one ever heard of a person training for a football or a baseball match, for a foot-race, for a rowing match, or for any other feat of strength, skill, or endurance, ever drinking any alcoholic liquors, or using tobacco, opium, or morphine. If they were good things, they would surely be

used under these circumstances where strength and endurance are required; if they were not injurious, they would not be prohibited. The cigarette is denied the college boy who is training for the college game; and if he breaks the rule, he is debarred from the games because the trainers know that such practice on his part weakens his heart and his wind, and that even one cigarette may result in the loss of a closely contested game requiring endurance on the part of every player.

Drunkenness. — Too much alcohol taken into the body will make the person who drinks it intoxicated or drunk. He staggers, sees double, cannot talk plainly, is foolish and silly in his talk, and cannot think well; or he becomes excited and violent, wants to fight, imagines that he is being insulted, and, crazed as he is, sometimes even kills his best friend.

After a while the drunken man, like the whipped horse, becomes exhausted. His muscles, his brain and his whole body are tired out by the extra work the stimulants have made them do, and he falls into a drunken sleep, from which he cannot be easily aroused; the narcotic effect of the alcohol has shown itself. Indeed, it not infrequently happens that the poor drunkard does not wake up at all; but his heart and brain, worn out by the over-stimulation of the alcohol he has drunk, stop working, and he dies, like the horse which has been lashed beyond his strength by his cruel driver.

How often it happens that drunken men commit murder; many railroad accidents, bringing death or terrible injuries to thousands of people, have been due to the alcohol-beclouded brains of engineers, switchmen and train dispatchers. Our prisons and jails are crowded with convicts, most of them young men, who committed some crime while under the influence of liquor, not necessarily drunk, maybe having taken only a glass or two. Railroad, bank, and steamship companies, which are responsible for lives and property, have found by experience that it is not safe to employ men who use liquor habitually, even though they never become intoxicated.

Criminals. — The great majority of our criminals, a large share of our insane, very many of our deaths, most of our murders, practically all the poverty, want, starvation and sickness in the crowded portions of our cities, are due directly or indirectly to the use of liquor.

Many people, it is true, drink wine and beer and even whisky and

never become drunkards. But any boy or young man who does this runs a great risk of becoming a slave to alcohol and ruining his health, even if he does nothing worse.

Tobacco. — Tobacco, like alcohol, is both a stimulant and a narcotic; it affects the heart and the nervous system. It is not so dangerous to life as alcohol; it does not fill our jails and insane asylums as alcohol does. But it is particularly injurious to the growing boy. It weakens his heart and disturbs his nervous system and dulls his brain.

Many boys use tobacco and think that it does them no harm. But let them go to a doctor and have their hearts examined, and it will be found that that organ is weaker than it should be. If tobacco-using boys are attacked by such diseases as typhoid fever or pneumonia, they are much more liable to die from heart failure than if they had not used tobacco. Such boys cannot run so fast nor so far, play marbles, football, or baseball so well or do any athletic feat so skillfully, as they could if they did not use tobacco. These are well-established medical facts, so well known that no person who is training boys or men for any game or athletic event will permit any of those under his care to use tobacco in any form.

Grown-up people can use tobacco, as they can alcohol, with less danger to themselves than growing boys can. But even adults who use tobacco are liable to have weak hearts. In fact, many men are refused life insurance because their hearts are weakened by tobacco. Such men are liable to die from heart failure if they run for a street car or make any unusual exertion, and pneumonia or any other severe attack of illness is liable to kill them.

It is true some boys use tobacco and do not appear to be injuriously affected by it, and many men use it and die of old age. But it is the fact, nevertheless, and all medical men will bear witness to the truth of it, that many boys ruin their health by using tobacco, and that no boy can be so strong, so quick, so skillful at his games, or so easily get through school, if he smokes cigarettes or uses tobacco in any form. If these things are true, and they are true, any boy who uses tobacco is foolish.

To this many boys will reply, "Isn't a man who uses tobacco foolish?" Yes, he is. But the danger and damage from tobacco to the growing boy are greater than to the grown man, simply because the boy is growing and the man is grown.

Opium.—Opium is the dried juice of a certain kind of poppy. It contains a number of different substances, one of which is morphine, to which it principally owes its narcotic and stimulant effects.

Opium is used by the people of some nations as a stimulant. The Chinese, for instance, are addicted to the vice, and many of our people have learned from them to smoke opium. Most of our confirmed criminals, the poor outcasts who spend most of their lives in prison, are slaves to the alcohol and opium habits. In almost every Chinatown in California may be found rooms where opium is smoked by white people, and most of the poor victims of this terrible habit are youths and young men. This is so because grown people seldom get close enough to the Chinese to acquire the habit, only idle boys and youths having time and inclination to loiter about the Chinese quarters. Those who learn to use opium soon resort to crime to get money with which to buy the deadly stuff, and soon go to jail, or else die. So that the white patrons of the opium dens are mostly young people.

It is pitiable, as well as disgusting, to see the poor fools who have become opium smokers. They have lost all sense of shame and are content to associate with the Chinese in their dirty, ill-smelling houses. They will borrow from their friends, if they have any, beg upon the streets, lie, steal, do almost anything that is shameful, in order to get a little money with which to buy opium. They are pale, trembling and haggard; their clothes are dirty and ragged, and they soon go to prison for stealing, or as common vagrants, or they die.

A certain small proportion of those who use alcohol to excess reform; but one who becomes a slave to opium seldom if ever reforms. Like the horse that is used to the whip, his organs will not work without being lashed by the stimulating effects of the opium. If he be deprived of it, he cannot eat, and is nervous and ill-tempered. He cannot go to sleep until he is worn out, and when he does doze off he has horrible dreams. He cannot work, read, or enjoy himself in any way. All that he thinks about is opium. He aches in every bone and muscle and nerve, and his sufferings become so intense that he will stoop to any meanness or commit almost any crime to obtain the stuff that has deprived him of his manhood and made him a slave to a more cruel and unrelenting master than he who whips his poor horse to death.

Morphine.—Morphine is also used as a stimulant. The morphine user is, like the opium user, an absolute slave to the habit. Once begun, the

use of the stuff is very rarely if ever stopped. Its victims cannot work without it and soon become so unreliable that no one will employ them.

Yet both opium and morphine are medicines of the greatest value when used by physicians for the cure of disease. But used for any other purpose, or without the direction of a physician, they are deadly poisons, sure to bring those who use them to the lowest depths of degradation, sure to make them criminals and beggars, sure to send them down to shameful deaths and paupers' graves.

MILDER STIMULANTS.

Tea, Coffee and Cocoa, or Chocolate, are mild stimulants. But even they, when used to excess, may produce various nervous troubles. They act upon the heart and nervous system, and, like all other stimulants, should be carefully avoided by the young and growing.

PATENT MEDICINES.

There are many people who, though opposed to the use of alcoholic beverages of any kind, do not hesitate to take, as medicine, so-called "bitters" and other patent medicines, many of which contain alcohol in great or less quantities, and which, therefore, are as intoxicating as wine or beer or even whisky. Such people think that their health is bad; and they ascribe to "the medicine" the temporary stimulating effect of the alcohol, which, unknown to themselves, they are taking. Unconsciously they take more and more of the stuff, not realizing that they are becoming addicted to the liquor habit just as much as if they were drinking any other alcoholic liquors.

Such people would be very indignant if they were told that they were doing that which they condemn in others; viz., drinking intoxicating liquors. Yet such is the fact, and the worst part of it is that the alcohol usually found in such so-called "medicines" is of the cheapest, most poisonous kind, and, therefore, like the cheapest wines, beers, and whiskies, is very destructive to health.

GLOSSARY.

Albumen (*al-bū′-men*). The white of an egg.

Albumin (*al-bū′-min*). A proteid substance, the chief constituent of the body. Its molecule is highly complex, and varies widely within certain limits in different organs and in different conditions.

Albuminuria (*al-bū′-mi-nū′-ri-a*). The presence of albumin in the urine, indicating changes in the blood or in the kidneys.

Amylopsin (*am-i-lop′-sin*). A ferment said to exist in pancreatin.

Anabolism (*an-ab′-o-lizm*). Synthetic or constructive metabolism. Activity and repair of function; opposed to katabolism.

Arbor Vitae (*ar′-bor vī′-tē*). A term applied to the branched appearance of a section of the cerebellum.

Argon (*ar′-gon*). A newly discovered element similar to nitrogen (found in the air).

Arytenoid (*ar-i-tē′-noid*). Resembling the mouth of a pitcher, as the arytenoid cartilages of the larynx.

Atlas (*at′-las*). The uppermost of the cervical vertebrae (from the mythical Atlas who supported the Earth).

Auricle (*aw′-ri-kl*). The auricles of the heart are the two cavities between the veins and the ventricles. Also, the pinna and external meatus of the ear.

Axis (*ak′-sis*). The second cervical vertebra, on which the head, with the atlas, turns.

Bacterium (*bak-tē′-ri-um*), pl. bacteria. A genus of microscopic fungi characterized by short, linear, inflexible, rod-like forms — without tendency to unite into chains or filaments.

Biceps (*bī′-seps*). Biceps brachii, the flexor of the arm.

Bicuspid (*bi-kus′-pid*). Having two points; the bicuspid or premolar teeth; the bicuspid valve, between the left auricle and the left ventricle.

Brachial (*brā′-ke-al* or *brak′-i-al*). Pertaining to the arm.

Bronchus (*brong'-kus*), pl. bronchi. The two tubes into which the trachea divides opposite the third thoracic vertebra, called respectively the right and left bronchus.

Caffein (*kaf'-ē-in*). An alkaloid that occurs in the leaves and beans of the coffee-tree, in Paraguay tea, etc.

Canaliculus (*kan-a-lik'-u-lus*), pl. canaliculi. The crevices extending from lacunae, through which nutrition is conveyed to all parts of the bone.

Canine (*ka-nīn'* or *kā'-nīn*). The conical teeth between the incisors and the premolars.

Capillary (*kap'-i-lā-ri* or *ka-pil'-a-ri*). A minute blood-tube connecting the smallest ramification of the arteries with those of the veins.

Capsule (*kap'-sūl*). A tunic or bag that incloses a part of the body or an organ.

Carbohydrate (*kar-bo-hī'-drāt*). An organic substance containing six carbon atoms or some multiple of six, and hydrogen and oxygen in the proportion in which they form water; that is, twice as many hydrogen as oxygen atoms. Starches, sugars, and gums are carbohydrates.

Cardiac (*kär'-di-ak*). Pertaining to the heart.

Carotid (*ka-rot'-id*). The principal right and left arteries of the neck.

Carpus (*kär'-pus*). Belonging to the wrist; as the carpal bones.

Cartilage (*kär'-ti-lāj*). Gristle of various kinds, articular, etc.

Casein (*kā'-se-in*). A derived albumin, the chief proteid of milk, precipitated by acids and by rennet at 40°C.

Cecum (*sē'-kum*). The large blind pouch or cul-de-sac, in which the large intestine begins.

Centrum (*sen'-trum*). The center or middle part; the body of a vertebra, exclusive of the bases of the neural arches.

Cerebellum (*ser-ē-bel'-um*). The inferior part of the brain, lying below the cerebrum.

Cerebrum (*ser'-ē-brum*). The chief portion of the brain, occupying the whole upper part of the cranium.

Cervical (*ser'-vi-kal*). Pertaining to the neck, as cervical vertebrae.

Chordae tendineae (*kor'-dē*). The tendinous cords connecting the fleshy columns of the heart with the auriculo-ventricular valves.

Choroid (*kō'-roid*). The second or vascular coat of the eye, continuous with the iris in front, and lying between the sclerotic and the retina.

Chyle (*kīl*). The milk-white fluid absorbed by the lacteals during digestion.

Chyme (*kīm*). Food that has undergone gastric digestion, and has not yet been acted upon by the biliary, pancreatic, and intestinal secretions.

Cilium (*sil′-i-um*), pl. ciliä. The eyelashes; also the hair-like appendages of certain epithelial cells, whose function is to propel fluid or particles along the passages that they line.

Ciliary (*sil′-i-a-ri*). Pertaining to the eyelid or eyelash; also by extension to the ciliary apparatus or the structure related to the mechanism of accommodation. Pertaining to the cilia.

Circumvallate (*sir-kum-val′-āt*). Surrounded by a wall or prominence, as the circumvallate papillae on the tongue.

Clavicle (*klav′-i-kl*). The collar-bone.

Coccyx (*kok′-siks*). The last bone of the spinal column, formed by the union of four rudimentary vertebrae.

Cochlea (*kok′-lē-a*). A cavity of the internal ear, resembling a snail-shell.

Conjunctiva (*kon-jungk-tī′-vä*). The mucous membrane covering the anterior portion of the globe of the eye, reflected on, and extending to, the free edge of the lids.

Corpus Arantii (*kor′-pus*). The tubercles, one in the center of each segment of the semilunar valves.

Corpuscle (*kor′-pus-l*). A name loosely applied to almost any small, rounded or oval body, as the blood corpuscles.

Cortex (*kor′-teks*). Bark. The outer layer of gray matter of the brain; the outer layer, cortical substance, of the kidney.

Cricoid (*krī′-koid*). Ring-shaped, as the cricoid cartilage of the larynx.

Dentine (*den′-tin*). The ivory-like substance constituting the bulk of the tooth, lying under the enamel of the crown and the cement of the root.

Diabetes (*dī-a-bē′-tēz*). The name of two different affections, *diabetes mellitus*, or persistent glycosuria, and *diabetes insipidus*, or polyuria, both characterized, in ordinary cases, by an abnormally large discharge of urine. The former is distinguished by the presence of an excessive quantity of sugar in the urine.

Dialysis (*dī-al′-i-sis*). The operation of separating crystalline from colloid substances by means of a porous diaphragm, the former

passing through the diaphragm into the pure water upon which the dialyzer rests.

Digastric (*di-gas'-trik*). Having two bellies, as the digastric muscle, enlarged near each end and with a tendon in the middle.

Duodenum (*dū-ō-dē'-num*). The first part of the small intestine, beginning with the pylorus.

Emulsion (*ē-mul'-shun*). Water or other liquid in which oil, in minute subdivision of its particles, is suspended.

Enamel (*en-am'-el*). The hard covering of the crown of a tooth.

Endothelium (*en-do-thē'-li-um*). The internal lining membrane of serous, synovial, and other internal surfaces, the homolog of epithelium.

Enzyme (*en'-zim*). Any chemic or hydrolytic ferment, as distinguished from organized ferments such as yeast; unorganized ferment.

Epiglottis (*ep-i-glot'-is*). A thin fibro-cartilaginous valve that aids in preventing food and drink from passing into the larynx.

Esophagus (*ē-sof'-a-gus*). The musculo-membranous tube extending from the pharynx to the stomach.

Eustachian (*u-stā'-ki-an*). Eustachian tube, the tube leading from the middle ear to the pharynx.

Facet (*fas'-et*). A small plane surface. The articulating surface of a bone.

Femur (*fē'-mer*). The thigh-bone.

Ferment (*fer'-ment*). Any micro-organism, proteid, or other chemic substance capable of producing fermentation, i.e., the oxidation and disorganization of the carbohydrates.

Fibrin (*fi'-brin*). A native albumen or proteid, a substance that, becoming solid in shed blood, plasma, and lymph, causes coagulation of these fluids.

Fibula (*fib'-u-lă*). The smaller or splint bone in the outer part of the leg, articulating above with the tibia, and below with the astragalus and tibia.

Filiform (*fil'-i-form*). Thread-like, as the filiform papillae.

Frontal (*fron'-tal*). Belonging to the front, as the frontal bone.

Fungiform (*fun'-ji-form*). Having the form of a mushroom, as fungiform papillae.

Ganglion (*gang'-gli-on*), pl. ganglions or gangliā. A separate and semi-independent nervous center, communicating with other ganglia or nerves, with the central nervous system, and peripheral organs.

Gastric (*gas'-trik*). Pertaining to the stomach.

Gelatin (*jel'-a-tin*). An albuminoid substance of jelly-like consistence, obtained by boiling skin, connective tissue, and bones of animals in water. The glue of commerce is an impure variety.

Glosso-pharyngeal (*glos'-o-fa-rin'-je-al*). Pertaining to the tongue and larynx.

Gluten (*glö'-ten*). A substance resembling albumin, and with which it is probably identified; it occurs abundantly in the seeds of cereals.

Glycogen (*glī'-ko-jen*). A white amorphous powder, tasteless and odorless, forming an opalescent solution with water, and insoluble in alcohol. It is commonly known as animal starch. It occurs in the blood and in the liver, by which it is elaborated, and is changed by diastasic ferments into glucose.

Gustatory (*gus'-tā-to-ri*). Pertaining to the special sense of taste and its organs.

Hashish (*hash'-ēsh*). A preparation from Indian hemp, Cannabis indica. It is a powerful narcotic.

Haversian (*ha-ver'-zian*). Haversian canal, in bone, a central opening for blood-tubes, surrounded by a number of concentric rings, or lamellae, of bone.

Hemoglobin (*hem-ō-glō'-bin*). A substance existing in the corpuscles of the blood, and to which their red color is due.

Hepatic (*hē-pat'-ik*). Pertaining or belonging to the liver.

Hilum (*hī'-lum*). A small pit, scar, or opening in an organic structure; the notch on the internal or concave border of the kidney.

Humerus (*hū'-me-rus*). The bone of the upper arm.

Humor (*hū'-mor*). Any liquid, or semi-liquid, part of the body.

Hyoid (*hī'-oid*). Having the form of the letter U. The hyoid bone situated between the root of the tongue and the larynx, supporting the tongue and giving attachment to its muscles.

Hypo-glossal (*hī-pō-glos'-al*). Under the tongue.

Iliac (*il'-i-ak*). Pertaining to the ilium, or region of the flanks, as iliac artery, vein, etc.

Incisor (*in-sī'-sor*). The chisel-shaped front teeth.

Inhibition (*in-hi-bish'-un*). The act of checking, restraining, or suppressing; any influence that controls, retards, or restrains. Inhibitory nerves and centers are those intermediating a modification, stoppage, or suppression of a motor or secretory act already in progress.

Innominate (*i-nom′-i-nāte*). Nameless; a term applied to several parts of the body to which no other definite name has been given, as the innominate bone, artery, vein, etc.

Invertin (*in′-ver-tin*). A ferment found in the intestinal juice, and also produced by several species of plants; it converts cane-sugar in solution into invert sugar.

Jugular (*jö′-gū-lär*). Pertaining to the throat, as the jugular vein.

Katabolism (*ka-tab′-ō-lizm*). Analytic or destructive metabolism; a physiologic disintegration; opposed to anabolism.

Lacrymal (*lak′-ri-mal*). Having relation to the organs of the secretion, transfer, or excretion of tears.

Lacuna (*lā-kū′-nä*). A little hollow space; especially the microscopic cavities in bone occupied by the bone corpuscles, and communicating with one another and with the haversian canals and the surfaces of the bone through the canaliculi.

Lamella (*lā-mel′-ä*), pl. lamellae. A thin lamina, scale, or plate; of bone, the concentric rings surrounding the haversian canals.

Larynx (*lar′-ingks*). The upper part of the air passage between the trachea and the base of the tongue; the voice-box.

Legumin (*lē-gū′-min*). A proteid compound in the seeds of many plants belonging to the natural order Leguminosae (peas, beans, lentils, etc.).

Lumbar (*lum′-bär*), pertaining to the loins, especially to the region about the loins.

Lymphatic (*lim-fat′-ik*). Pertaining to lymph.

Lymphatics (*lim-fat′-iks*). The tubes that convey lymph.

Lymphatic glands. The glands intercalated in the pathway of the lymphatic tubes, through which lymph is filtered.

Massage (*ma-säzh′*). A method of effecting changes in the local and general nutrition, action and other functions of the body, by rubbing, kneading, and other manipulation of the superficial parts of the body by the hand or an instrument.

Masseter (*mas′-e-ter*). A chewing-muscle felt on the angle of the jaw.

Medullary (*med′-u-lā-ri*). Pertaining to the medulla, or marrow; resembling marrow. Also pertaining to the white substance of the brain contained within the cortical envelop of gray matter.

Mesenteric (*mez-en-ter′-ik*). Pertaining to the mesentery, as artery, vein, etc.

Mesentery (*mez′-en-ter-ĭ*). A fold of the peritoneum that connects certain portions of the intestine with the dorsal abdominal wall.

Metabolism (*me-tab′-ō-lizm*). A change in the intimate condition of cells; (1) constructive or synthetic metabolism is called Anabolism; in anabolism, the substance is becoming more complex and is accumulating force; (2) destructive or analytic metabolism is called Katabolism; in katabolism there is disintegration, the material is becoming less complex, and there is loss or expenditure of force.

Metacarpus (*met-a-kär′-pus*). The bones of the palm of the hand.

Metatarsus (*met-a-tär′-sus*). The five bones of the arch of the foot, situated between the tarsus and the phalanges.

Mitral (*mī′-tral*). Resembling a miter; mitral valve, with two flaps, between the left auricle and the left ventricle.

Molar (*mō′-lär*). Mill; the grinding-teeth.

Mucous (*mū′-kus*). A term applied to those tissues that secrete mucus.

Mucus (*mū′-kus*). A viscid liquid secretion of mucous membranes, composed essentially of mucin, holding in suspension desquamated epithelial cells, etc.

Myosin (*mī′-o-sin*). A proteid of the globulin class, — the chief proteid of muscle. Its coagulation after death causes *rigor mortis*.

Narcosis (*när-kō′-sis*). The deadening of pain, or production of incomplete or complete anesthesia by the use of narcotic agents, such as anesthetics, opium, and other drugs.

Narcotic (*när-kot′-ic*). A drug that produces narcosis.

Neural (*nū′-ral*). Pertaining to the nerves.

Neuroglia (*nū-rog′-li-ä*). The reticulated framework or skeleton-work of the substance of the brain and spinal cord. The term is sometimes abbreviated to glia.

Nucleus (*nū′-klē-us*). The essential part of a typical cell, usually round in outline, and situated in the center.

Occipital (*ok-sip′-i-tal*). Pertaining to the occiput or back part of the head, as the occipital bone.

Odontoid (*o-don′-toid*). Resembling a tooth; the tooth-like process (axis) of the second cervical vertebra, on which the atlas turns.

Olfactory (*ol-fak′-tō-ri*). Pertaining to the sense of smell.

Osmosis (*os-mō′-sis*). That property by which liquids and crystalline substances in solution pass through porous septa; endosmosis and exosmosis.

Oxy-hemoglobin (*ok-si-hem-ō-glo'-bin*). Hemoglobin united, molecule for molecule, with oxygen. It is the characteristic constituent of the red corpuscles to which the scarlet color of arterial blood is due.

Pancreas (*pan'-krē-as*). A large racemose gland lying transversely across the dorsal wall of the abdomen. It secretes a clear liquid for the digestion of proteids, fats, and carbohydrates. The sweetbread of animals, vulgarly called the "belly sweet-bread" in contra-distinction to the thymus, or true sweet-bread.

Pancreatin (*pan'-krē-a-tin*). The active element of the pancreatic juice.

Papilla (*pā-pil'-ä*), pl. **papillae**. Any soft, conical elevation, as papillae of the dermis, tongue, etc.

Papillary (*pap'-i-lā-ri*). Pertaining to a papilla; papillary muscles,—the conic muscular columns of the heart, to which the chordae tendineae are attached.

Parietal (*pä-rī'-e-tal*). Pertaining to the walls, as the parietal bone.

Parotid (*pa-rot'-id*). Near the ear, as the parotid salivary glands.

Patella (*pa-tel'-a*). The knee-pan.

Peptone (*pep'-tōn*). A proteid body produced by the action of peptic and pancreatic digestion.

Pericardium (*per-i-kär'-di-um*). The closed membranous sac or covering that envelops the heart.

Periosteum (*per-i-os'-tē-um*). A fibrous membrane that invests the surfaces of the bones, except at the points of tendinous and ligamentary attachments, and on the articular surfaces where cartilage is substituted.

Peristaltic (*per-i-stal'-tik*). The peculiar movement of the intestine and other tubular organs, consisting in a vermicular shortening and narrowing of the tube, thus propelling the contents onward. It is due to the successive contractions of the bundles of longitudinal and circular muscular fibers.

Peritoneal (*per-i-tō-nē'-al*). Pertaining to the peritoneum.

Peritoneum (*per-i-tō-ne'-um*). The serous membrane lining the interior of the abdominal cavity, and surrounding the contained viscera. The peritoneum forms a closed sac, but is rendered complex in its arrangement by numerous foldings produced by its reflection upon the viscera.

Phalanges (*fā-lan'-jēz*), plural of **phalanx** (*fā'-langks*). Any one of the bones of the fingers or toes.

Pharynx (*far′-ingks*). The cavity back of the soft palate. It communicates anteriorly with the posterior nares, laterally with the eustachian tubes, ventrally with the mouth, and posteriorly with the gullet and larynx.

Plasma (*plaz′-mä*). The original undifferentiated substance of nascent, living matter. The fluid part of the blood and lymph.

Pleura (*plö′-rä*). The serous membrane which envelops the lungs, and which, being reflected back, lines the inner surface of the thorax.

Plexus (*plek′-sus*). An aggregation of vessels or nerves forming an intricate net-work.

Pneumogastric (*nu-mō-gas′-trik*). Pertaining conjointly to the lungs and the stomach, or to the pneumogastric or vagus nerve.

Portal (*pōr′-tal*). Pertaining to the porta (gate) or hilum of an organ, especially of the liver, as the portal vein.

Postcaval (*pōst-kā′-val*). Pertaining to the postcava; the postcaval vein, formerly called the inferior vena cava, or vena cava ascendens.

Precaval (*prē-kā′-val*). Pertaining to the precava; the anterior caval vein, formerly called the superior vena cava, or vena cava descendens.

Pronation (*prō-nā′-shun*). The turning of the palm downward.

Protoplasm (*prō′-tō-plazm*). An albuminous substance, ordinarily resembling the white of an egg, consisting of carbon, oxygen, nitrogen, and hydrogen in extremely complex and unstable molecular combination, and capable, under proper conditions, of manifesting certain vital phenomena, such as spontaneous motion, sensation, assimilation, and reproduction, thus constituting the physical basis of life of all plants and animals.

Ptyalin (*tī′-a-lin*). An amylolytic or diastasic ferment found in saliva, having the property of converting starch into dextrin and sugar.

Pulmonary (*pul′-mō-na-ri*). Pertaining to the lungs.

Pylorus (*pī-lō′-rus*). The opening of the stomach into the duodenum.

Radius (*rā′-di-us*). The outer of the bones of the forearm.

Renal (*rē′-nal*). Pertaining to the kidneys.

Rennin (*ren′-in*). An enzyme, or ferment, to whose action is due the curdling or clotting of milk produced upon the addition of rennet.

Retina (*ret′-i-nä*). The chief and essential peripheral organ of vision; the third or internal coat or membrane of the eye, made up of the end organs or expansion of the optic nerve within the globe.

Sacrum (*sā'-krum*). A curved triangular bone, composed of five consolidated vertebrae, wedged between the two iliac (pelvic) bones, and forming the dorsal boundary of the pelvis.

Scapula (*skap'-ū-lä*). The shoulder-blade.

Sciatic (*sī-at'-ik*). Pertaining to the ischium; the sciatic nerve, the main nerve of the thigh.

Sclerotic (*sklē-rot'-ik*). Hard, indurated; pertaining to the outer coat of the eye.

Semilunar (*sem-i-lū'-när*). Resembling a half-moon in shape; semilunar valves, pocket-like valves at the beginning of the aorta and pulmonary artery.

Serous (*sē'-rus*). Pertaining to, characterized by, or having the nature of, serum.

Serum (*sē'-rum*). The yellowish fluid separating from the blood after the coagulation of the fibrin.

Solar plexus (*sō'-lär*). Solar, with radiations resembling the sun.

Sphincter (*sfingk'-ter*). A muscle surrounding and closing an orifice.

Splenic (*splen'-ik*). Pertaining to the spleen.

Steapsin (*stēp'-sin*). A diastasic ferment which causes fats to combine with an additional molecule of water and then split into glycerine and their corresponding acids.

Sternum (*ster'-num*). The breast-bone.

Subclavian (*sub-klā'-vi-an*). Situated under the collar-bone; subclavian artery and vein.

Sublingual (*sub-ling'-gwal*). Lying beneath the tongue, as sublingual gland.

Submaxillary (*sub-mak'-si-la-ri*). Lying beneath the lower maxilla, as submaxillary salivary gland.

Supination (*sū-pi-nā'-shun*). The turning of the palm upward.

Synovia (*sī-no'-vi-ä*). The lubricating liquid secreted by the synovial membranes in the joints.

Tarsus (*tär'-sus*). The instep, consisting of seven bones.

Temporal (*tem'-pō-ral*). Pertaining to the temples, as temporal artery, vein, muscle, etc.

Tetanus (*tet'-a-nus*). A spasmodic and continuous contraction of the muscles, causing rigidity of the parts to which they are attached.

Thein (*thē'-in*). An alkaloid found in tea.

Theobromin (*thē-ō-brō'-min*). A feeble alkaloid obtained from cacao-butter; the essential substance found in cocoa and chocolate.

Thyroid (*thī′-roid*). Shield-shaped, as the thyroid cartilage of the larynx.

Tibia (*tib′-i-ä*). The larger (inner) of the two bones of the leg, commonly called the shinbone.

Trachea (*trā-kē′-a* or *trā′-ke-a*). The windpipe.

Triceps (*trī′-seps*). Triceps of the arm, the extensor of the arm, lying along the back of the humerus.

Tricuspid (*trī-kus′-pid*). Having three cusps or points, as the tricuspid valve.

Trypsin (*trip′-sin*). The proteolytic ferment of pancreatic juice.

Ulna (*ul′-nä*). The larger (inner) of the two bones of the forearm.

Ureter (*ū-rē′-ter*). The tube conveying the urine from the pelvis of the kidney to the bladder.

Vaso-constrictor (*vas′-ō-kon-strik′-tor*). Causing a constriction of the blood-vessels.

Vaso-dilator (*vas′-ō-di-lā′-tor*). Pertaining to the positive dilating motility of the non-striated muscles of the vascular system.

Vaso-motor (*vas-ō-mo′-tor*). Serving to regulate the tension of the blood-vessels, as vaso-motor nerves; including vaso-dilator and vaso-constrictor mechanisms.

Ventricle (*ven′-tri-kl*). Applied to certain structures having a bellied appearance. The cavities of the heart from which the blood is forced out through the arteries.

Vesicle (*ves′-i-kl*). A small, membranous, bladder-like formation, as air vesicle.

Villus (*vil′-us*), pl. villi. One of the numerous minute vascular projections from the mucous membrane lining the small intestine, for absorbing digested food.

Vitreous (*vit′-re-us*). Glass-like, as the clear, jelly-like, vitreous humor of the eye.

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